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Tobacco Diseases

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Tobacco Diseases

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CAUSES OF TOBACCO DISEASES

Tobacco diseases may be considered as abnormalities of the plant that cause reduced quality or quantity of the commercial product. This definition includes various malnutrition diseases caused by soil deficiencies, injuries caused by fungi, bacteria, round worms or nematodes, parasitic flowering plants such as broomrape, virus diseases, and "burning" of wilted plants. Insect injuries might be included, but are not discussed in this bulletin. If it is kept in mind that diseases may be produced by one or a combination of these causes, it will be easier to understand the reasons for the various control measures recommended and the changes which are made from time to time in these recommendations as new facts are discovered. A short description of the organisms that cause disease may be of interest to those unacquainted with the lower forms of life.

Fungi are plants of a low order, such as the mushrooms and various molds that grow in damp places. A common fungus familiar to all is the green mold sometimes seen on canned fruit. Certain forms of fungi are common causes of plant disease. They subsist either on the living plant cells, as rust of wheat and other cereals, and mildews of various crops, or by killing the plant cells and living on the dead tissues, as in fruit rots or the black root-rot of tobacco.

Bacteria are sometimes classed as one of the groups of fungi. They are single-celled plants. The individual cells are visible only with a microscope. A mass of them, however, may be readily visible to the unaided eye.

Virus diseases are caused by organisms the individual particles of which are too small to be seen with an ordinary microscope but their images can be seen and the particles photographed with an electron microscope. The virus content of the plant increases rapidly following infection but the exact method of reproduction is not known. The viruses are characterized by being able to multiply only in living cells.

Nematodes are round worms that can sometimes be seen with the unaided eye. They are similar to the hookworm of the human and to round worms causing trouble in many animals.

Parasitic flowering plants are plants such as broomrape, dodder, and mistletoe that have become adapted to obtaining food materials or nutrients directly from some other living plant instead of from the soil.

Physiological diseases, or those not caused by disease-producing organisms, often result from a lack of sufficient available nutrients or an excess of one or more of the compounds necessary for plant growth. The quantity of available nutrients in the soil is determined in part by the total content of the necessary minerals in the soil and the degree to which the land has been cropped and manured.

For example, alfalfa removed for hay reduces the available mineral content of the soil rapidly, because of the heavy yields produced, unless part of the nutrients are returned in the manure from feeding the crop. Legumes or legume-grass mixtures, if left on the land or turned under, tend to accumulate available nutrients. Close pasturing of grassland may reduce available nutrients, especially if the droppings are deposited in restricted areas, such as shady places in the field. Therefore, the fact that a bluegrass sod has not been plowed for many years is no assurance that it will make good tobacco land.

SOIL IN RELATION TO TOBACCO DISEASES

Growers are well aware of the desirability of selecting the most favorable soil for tobacco. The reasons for the selection or rejection of certain soils for tobacco are not always well understood but are usually arrived at by experience. The relation of soil to diseases will be discussed more fully under the specific diseases but reference is made here to a few of the more obvious relations.

Soil fertility.— Tobacco makes an enormous growth in a very short period; consequently a high level of available nitrogen, phosphorus, and potassium should be present in the soil when the crop is set. Lack of enough of any one of these nutrients results in slow growth, late maturity, excessive firing, or may aggravate leaf-spot diseases of one kind or another.

Soil reaction.— Soil reaction or the degree of its acidity or alkalinity appears to be an important factor. Experience has demonstrated that tobacco thrives best in moderately acid soil. The use of too much lime tends to increase black root-rot and quite often seems to be a contributing cause of frenching. In strongly acid soil toxic materials are liberated which, when taken into the plant, cause slow growth

and leaf spotting. On such soil a light application of ground limestone may prove beneficial to tobacco.[1]

Organic matter.— Organic matter, if well rotted and mixed with the soil, is generally beneficial to tobacco because it tends to increase fertility and reduce leaf-spot diseases. Manure is generally beneficial both to burley and to dark tobacco, but where successive crops of tobacco are grown in manured soil, black root-rot is almost certain to develop, unless a highly resistant variety is grown. Leaf mold, turned under in newly cleared land, sometimes causes tobacco to french if it is the first crop.

Crop rotation.— The grower should profit by experience and give careful study to selecting the crop to precede tobacco in a rotation. In spite of extensive studies on rotation for tobacco it is not possible at present to recommend any rotation as being best for tobacco. The burley industry was developed largely on the basis of a long-time sod-tobacco rotation, and this is still good if the sod has not been over-pastured and if the land has not become infested with meadow nematodes, small round worms that cause brown root-rot. There are many partial failures when tobacco follows old bluegrass sod, caused either by meadow nematodes or reduced fertility, particularly low available potash, resulting from overgrazing. Tobacco may grow slowly after corn, soybeans, timothy, orchard grass, and some of the meadow and pasture legumes, particularly in a season that is wet during or immediately following setting. The reason appears to be infestation with meadow nematodes. Alfalfa or other legumes cut for hay cause depletion of nutrients, particularly potash, and result in poor quality tobacco if it follows the legumes, unless the soil is well fertilized. Weeds make an excellent preparation for tobacco, presumably because only those weeds develop that are highly resistant to pathogenic organisms such as meadow nematodes, and consequently leave the soil relatively free from injurious organisms. A rotation that is commonly used in Kentucky is continuous tobacco with a cover crop of a small grain and hairy vetch. In fields that have been in this rotation or in a tobacco-small grain rotation for years, meadow nematodes are found in extremely small numbers, if at all, and tobacco grows rapidly following setting. Fertility can readily be kept to a high level if the land does not wash. With the rapid spread of black shank a rotation is to be preferred over continuous tobacco. If a few black shank plants in a field one year are disregarded they may result in

[1] For recommendations on fertilizing soil for tobacco see Kentucky Experiment Station Circular 70.

heavy loss the next year. Rotation will greatly reduce the chance of appreciable loss.

Physical condition of soil.— Good physical condition of the soil is desirable, especially good surface and under drainage. Tobacco often frenches on soil too wet, or if water stands long about the plants it may cause them to wilt, turn yellow, and finally die. On hard, poorly aerated soil tobacco grows slowly and produces inferior leaf. Loose, open soil is likely to make rapid-growing, high-quality tobacco, if the necessary nutrients are available.

PHYSIOLOGICAL DISEASES

Physiological diseases may be caused by either temporary or extended lack or excess of certain elements in the soil. Nitrogen, phosphorus, and potassium are the three elements most likely to be deficient in Kentucky soils. Magnesium deficiency, which causes sand drown, and calcium deficiency, which causes irregularly shaped leaves, rarely, if ever, occur. Growth of large, well-formed leaves of high quality largely depends on the proper nourishment of the plant. Therefore much attention should be paid to soil improvement and to the kind and amount of fertilizer used.

Nitrogen Deficiency

Deficiency of nitrogen is indicated by slow-growing, light-green plants. Yellowing and firing of the lower leaves during dry periods often is caused by lack of nitrogen and is a common example of nitrogen starvation. An abundance of available nitrogen in the soil, if other necessary elements and moisture are present, produces rapid-growing, vigorous, dark-green plants, except possibly during very hot spells, when the lower leaves may yellow. In dry seasons when plants grow slowly and fire badly, much of the damage commonly attributed to a lack of water is actually caused by lack of available nitrogen and potassium. With a proper supply of available nitrogen in the soil burley tobacco will commence to yellow at about topping time.

Prevention: A heavy grass-legume sod turned under will usually furnish sufficient nitrogen. Liberal applications of manure or fertilizer high in nitrogen prevent nitrogen starvation. Nitrogen fertilizers may be applied as a side-dressing after tobacco is set. An oversupply causes plants to remain green long after topping.

Phosphorus Deficiency

Slow-growing, stunted, dark-green, late maturing plants usually indicate lack of phosphorus, but under certain conditions other symp-

Fig. 1.— Phosphorus starvation in burley tobacco. This type of spotting occurs soon after growth begins on plants which were well-nourished in the plant bed but set in a field having very little available phosphorus. When the plant becomes adjusted to the low phosphate level, spotting is no longer produced.

toms may develop. Tobacco plants from a well-fertilized bed set in soil very deficient in phosphorus may turn a yellowish green in the older leaves and suddenly develop numerous dead spots in these leaves during the first few weeks after setting (Fig. 1). As the roots spread out in the soil and the plants adjust their growth to the available phosphorus the later leaves are dark green. This condition cannot be recognized readily as phosphorus deficiency unless plants well supplied with phosphorus and sufficient lime are growing nearby for comparison. Lack of available phosphorus appears to be a common cause of slow growth and late maturity of tobacco in most parts of Kentucky outside the central Bluegrass area, and in certain places within it.

Prevention: Unless a field to be used for tobacco is known to have plenty of available phosphorus a phosphate fertilizer or a mixed fertilizer high in phosphorus should be liberally applied. Manure is low in phosphorus and cannot be relied upon to correct phosphorus deficiency.

Potassium Deficiency

Although Kentucky soils generally are high in total potassium, tobacco frequently shows signs of potash starvation. This is because

the rate at which potash becomes available in the soil is not great enough to meet the needs of the tobacco crop, which requires a large amount in a short time.

In 1941 over half the fields set to tobacco in central Kentucky were found to be too low in available potash to produce a satisfactory crop. A similar condition exists in many fields set to tobacco each year outside central Kentucky. Potash starvation is often more obvious on heavily limed than on unlimed soil. For example, tobacco grown near an old limestone road, where limestone dust has been settling for many years, often shows marked potash starvation whereas that at a distance from the road may show little or none.

Potash starvation is readily recognized in tobacco. A mild deficiency may cause merely the rolling of the edges of the leaves downward or bronze-yellow blotches on the leaves, especially on the tips of the upper leaves (Fig. 2). In more severe cases the leaves are curled downward at the edges or are "rimbound" and the tips and edges may die and turn dark. The portions of the blade of the leaf between the larger veins are curved upward as if the veins were too short. The leaf usually is light green with yellowish blotches, and

Fig. 2.— A mild case of potassium starvation of burley tobacco. Dead spots are just developing on the two leaves at the left. More severe starvation results in rim firing and in death of leaf tips.

the whole plant may have a distinct bronze tinge. Where there is not enough potash but plenty of nitrogen the tobacco is red or dark brown when cured but where there is enough available potash, phosphorus, and nitrogen, both the yield and quality of the tobacco are high.

Prevention: Potassium starvation may be prevented by applying barnyard manure, potash fertilizers, or liberal quantities of mixed fertilizers that contain a high percentage of potash. Muriate of potash, if used in excess, may cause cured tobacco to stay in case, and burn poorly. To prevent this not more than 50 pounds of potash in the muriate form should be applied per acre. This is the amount contained in 500 pounds of 5-10-10 fertilizer. If more potash is required it should be applied as sulfate of potash. Land known to be low in available potash will require about 1500 pounds per acre of 5-10-10 fertilizer to meet the potash requirement. Where tobacco is grown continuously in the same field it is probably better to use still less muriate of potash, because of the danger of building up the chlorine content of the soil.

Manganese Toxicity

Tobacco set in very acid soil (pH below 5.0) is likely to develop manganese toxicity. The plants grow slowly following setting, turn light green or yellowish between the larger veins, and gradually develop numerous dead spots, particularly in the older leaves. There is something in common between the appearance of manganese toxicity and the spotting caused by phosphorus starvation, but the conditions appear to be distinct. A similar condition may develop in the winter cover crop that follows tobacco. Sometimes plants recover and develop a normal green color in later leaves, possibly because the soil becomes less acid following decomposition of the cover crop. The addition of lime to the soil immediately following recognition of the trouble has been reported to bring about quick recovery. It prevents the trouble from occurring in subsequent crops.

Sulfur Deficiency

A condition sometimes occurs on the tips of ripening leaves of burley tobacco that is thought to be caused by insufficient sulfur. The affected leaves are green at the base but the tips are grayish yellow, the yellow sometimes extending well down the edges of the leaves. Affected leaves yellow and dry out slowly after cutting. When cured the tip of an affected leaf is honey yellow and the remainder is brown (Fig. 3).

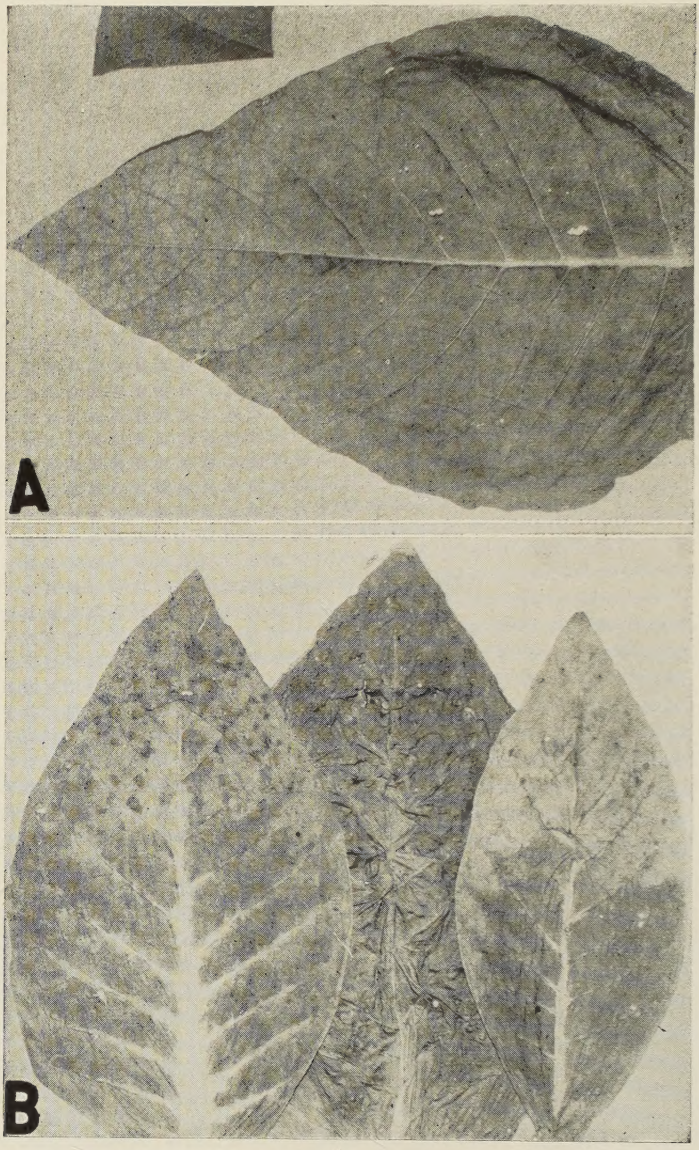

Fig. 3.— (A) Uncured leaf of burley tobacco. The chlorotic tip closely resembles sulfur deficiency. A small bit of leaf from a normal green leaf is shown for comparison. (B) Two chlorotic leaves and a normal leaf (center) when nearly cured. The mid and lateral veins of the chlorotic leaves are still partly alive. The areas that were chlorotic before curing show clearly in the cured leaf.

Prevention: Sulfur deficiency occurs where the surface soil has been removed by erosion and the land is hard and rain will not soak in readily. Tobacco growing on unfertilized land gets a large part of its sulfur in the rain. A long dry period followed by heavy, washing rain and rapid plant growth is believed to induce symptoms of sulfur deficiency. There is probably no reason for attempting to prevent sulfur deficiency in burley tobacco in Kentucky. Sulfur-containing fertilizers such as ordinary superphosphate and sulfate of potash should be effective in overcoming it.

Frenching

Frenching, or wet-weather french, though sometimes confused with mosaic of tobacco, is a distinct disease. Newly frenched plants are nearly white in the growing point (Fig. 4). The frenched leaves are narrowed and drawn and the tips sometimes bend sharply downward forming a cup of the underside of the leaf. Later, affected leaves may turn dark green. In severe cases the leaves may be reduced to narrow straps made up mostly of the midvein, and the number of leaves greatly increased, sometimes to hundreds on a plant.

Fig. 4.— Frenching of burley tobacco.

Frenching develops under a variety of conditions. It is more prevalent in seasons of abundant rainfall and nearly absent during protracted dry periods. If the soil moisture content is reduced before numerous lateral buds start growth, the plants may recover completely.

Frenching occurs in soil that is near the neutral point (about pH 6 or above),[1] but plants growing in soil of the most desirable acidity for tobacco (about pH 5.6 or below) are not likely to french. Studies of the disease in the greenhouse have shown that frenching sometimes is associated with a lack of available nitrogen in the soil, but at other times it seems to occur in the presence of available nitrogen when some other nutrient, as phosphorus, is deficient. Frenched plants sent in for determination of the disease are usually high in nitrates.

In Kentucky frenching is frequently found on soil that has been limed, either intentionally or by limestone dust blowing or washing from a road onto the neighboring field. In fertile soil liming may not induce frenching in the growing crop but it may appear after topping, in the suckers. Frenching and a low level of available potash are frequently associated, but there is little evidence that there is a causal relation between low available potash and frenching.

Studies made at the United States Department of Agriculture, by Steinberg, indicate that frenching can be caused by a toxin formed by *Bacillus cereus*, a saprophyte common in all soils, that grows on the surface of roots. The bacteria increase 60 to 200 percent when field plants french. Isoleucine, an amino acid, increases in frenched leaves, due to the action of the toxin, and in turn causes the visual symptoms characteristic of frenching.

Prevention: Frenching can always be prevented in the greenhouse by sufficient applications of the necessary fertilizing elements. In the field, prevention is not so simple because of the variety of conditions under which the disease occurs. Addition of rotted manure or other organic matter that decays readily, proper soil drainage, and application of fertilizers recommended for tobacco, probably will be beneficial in soil known to produce the disease. If a liming material is to be used on tobacco land apply a small quantity following the tobacco crop rather than immediately preceding it. Fertilizers containing con-

[1] The term pH refers to acidity or alkalinity. A neutral soil has a pH of 7. Figures smaller than 7 indicate degrees of acidity; figures larger than 7, degrees of alkalinity. The smaller the figures below 7, the stronger the acidity. The soils of the Bluegrass region are about pH 5.6 except in the hilly area where alfalfa can be grown without liming. Here the pH is about 7. The soils of the rest of the state are slightly more acid.

siderable quantities of ground limestone as a filler should not be used for tobacco.

PLANT-BED DISEASES

Under this heading only those diseases that are confined to the plant bed are discussed. Angular leaf-spot, wildfire, mosaic, and black root-rot affect plants both in the bed and in the field, and are discussed later.

Blue Mold

Following 1937, when blue mold caused extensive damage to plant beds in Kentucky, it appeared in some second-year beds and slowly spread to new beds, causing little damage. By 1944 it seemed to have disappeared completely from the state. Spores were again blown in in 1945, when another severe outbreak occurred. Carryover in second-year beds caused a moderately severe outbreak in 1946 and very mild outbreaks in 1947 and 1948. By 1951 the disease had again almost completely disappeared from the state. From past experience it appears that the disease if present will be generally severe in Kentucky only in years when plant beds are exceptionally early. Other years it will cause injury only in beds that are shaded or are late.

Fig. 5.— Blue mold showing spore masses on the under side of a leaf. These spores, when blown about, cause new outbreaks in the same bed and in beds at a distance.

The disease is caused by a fungus[1] that is common on wild tobacco, *Nicotiana repanda,* in Texas. It is probable that spores of the fungus blew from Texas to Florida in 1921, when it failed to become established in cigar tobacco, the only type grown at that time, and again in 1931 when it became firmly established in the recently developed flue-cured tobacco area of Georgia.

The fungus overwinters in the Georgia-Florida area on volunteer tobacco and probably as oöspores in old beds, and farther north in plant beds used the previous year. The disease usually appears about two weeks earlier in old beds than in new ones. It produces heavy-walled resting spores, or seed-like bodies, in the dying or dead leaves. These are capable of remaining in the soil at least a year and attacking the next crop of plants if the same site is used again for tobacco plants. After penetrating the leaves the fungus produces grape-like clusters of spores on the undersides of the leaves (Fig. 5). These can be seen in the early morning as a bluish moldy growth. These spores, carried by winds for long distances, rapidly spread the disease.

If the weather is dry, the first sign of the disease is likely to be yellowing and stunting of a group of half-grown plants.[2] These symptoms are very similar to those of nitrogen starvation. No other symptoms will likely appear unless the weather becomes wet, when infection may spread to other parts of the bed causing yellow leaf spots or large scalded areas on the leaves of plants about ready to set. Sometimes, in wet weather when the plants are tender, the leaves rot, making a stinking mass of plant material. If infection is mild, the plants may be set in the field without danger of dying, but if it is severe so that the stems of the plants are darkened near the ground line, they are almost certain to die if set in the field. If, however, the plants are given nitrate fertilizer and allowed to recover for about 10 days, they are satisfactory for setting.

Prevention and control: Since there have been only 3 moderately serious outbreaks of blue mold in Kentucky (1937, 1945, 1946) during the 18 years the disease has been present in Eastern United States, control measures are usually not necessary. It is good practice to locate beds in the open where they get no shade. This may delay an out-

[1] *Peronospora tabacina.*

[2] Blue mold rarely appears in the plant bed in Kentucky until setting time or a few days before. Outbreaks which begin in the bed during wet, cool periods when the plants are about one-fourth grown and kill many plants, are commonly attributed to blue mold but are usually wildfire or, in less severe cases, angular leafspot. These two plant-bed diseases can be prevented completely by treating the beds with bluestone-lime when the plants are small.

break a week or two. There are chemicals on the market such as ferbam and zineb[1] that have been found to be very effective in preventing the disease or slowing it down if it has already started. These materials can be used effectively either as a dust or spray. Directions for treatment can be obtained from county agents or from the Experiment Station at Lexington. A supply of one of them should be on hand during the plant-bed season in case an outbreak of blue mold occurs. Zineb may also be used to control leaf spot diseases of tomato.

Fertilizer Injury

If weather is dry in late April and early May, small tobacco plants ¼ to 2 inches across may turn yellow and die or, when touched, break off at the surface of the ground. Usually the area in the bed where this occurs has a white coating over the surface soil particles made up of salts carried to the surface by evaporating water. These salts injure the small roots of the plants and prevent growth of new roots from the crown. Such a condition is usually brought about by the grower applying too much fertilizer to the surface of the bed before sowing, or from excess of potash salts following burning a bed with wood. It is common practice to apply an 80-pound sack, and sometimes two sacks, of fertilizer on 100 feet of bed 12 feet wide. If the season is wet continuously no harm will result, but if the season is dry, even for short periods, plants in large areas of the bed may die. Similar injury sometimes follows the use of calcium cyanamide for weed control.

Prevention and control: Do not use over 25 pounds of a complete fertilizer such as 5-10-10 on a steamed bed 100 feet long and 12 feet wide. On a burned bed, where potash is abundant in the ash, use about 40 pounds of 20% superphosphate and apply nitrogen if necessary. If too much fertilizer has been used, or if the bed has been treated with cyanamide, and the plants are yellowing in a dry period, water them heavily to dilute the salts and carry them into the soil.

Cottonseed meal, tankage, or chicken manure is sometimes used as a nitrogen fertilizer on tobacco beds after the plants are up, but in several cases observed each of these caused the plants to yellow and sometimes decay. Injurious molds sometimes develop where the cottonseed meal falls on the leaves. Nitrate of soda and ammonium

[1] These materials are sold under various trade names. The name and amount of the active ingredient is stated on package labels. The active ingredient in ferbam is ferric dimethyl dithiocarbamate; in zineb it is zinc ethylene bisdithiocarbamate.

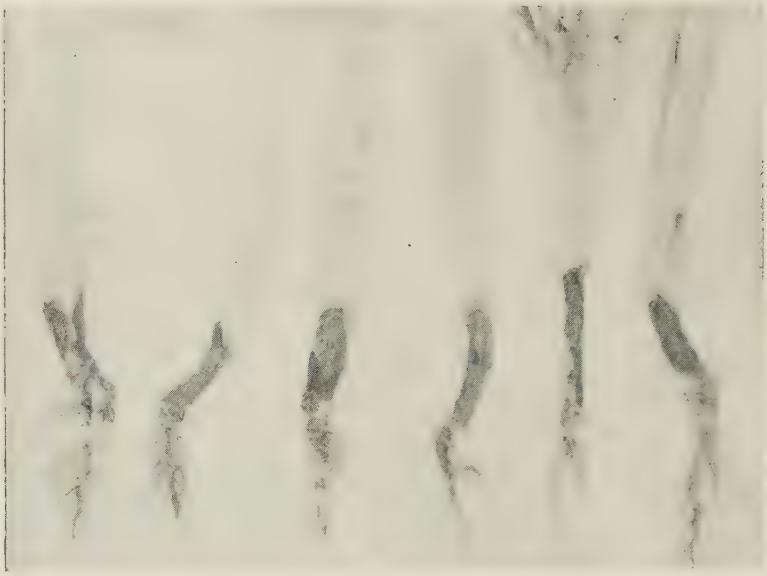

Fig. 6.— Blackleg of burley tobacco occurs in the plant bed as a soft rot, when the plants are about ready to set.

nitrate, if properly applied, are much more satisfactory sources of nitrogen where immediate results are wanted.

Blackleg

This disease occurs in the plant bed during wet periods when the plants are about ready to be set. It is a bacterial soft rot attacking leaves that touch the ground and spreading from them into the soft, tender stalk. The stalk may rot off completely, or if it has become somewhat hard the rot may spread up one side, splitting it open. The rotted areas usually turn black, hence the name (Fig. 6). Frequently the plants in an area up to 3 feet in diameter are destroyed. Slightly affected plants when set in the field grow normally if set in rather dry soil, but if the setting season is wet it is not advisable to use plants from an affected bed as repeated resetting may not give a satisfactory stand. If diseased plants are kept over night for setting the following day, all the plants may be a slimy rotten mass. The disease is caused by *Bacillus aroideae*, one of the group of soft-rot bacteria carried by certain insects. The method of entrance into the bed is not known, but it may be by insects. The disease seems to be less frequent in beds treated with bluestone-lime mixture.

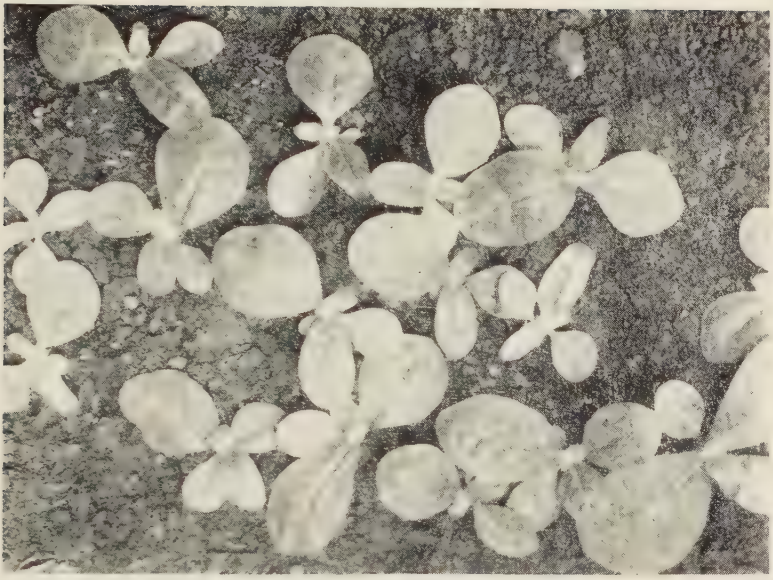

Fig. 7.— Cold injury to burley tobacco plants in the plant bed, following a cold, windy night. The same type of injury occurs on dark tobacco.

Cold Injury

This trouble often appears on plants in the bed which are exposed to the weather by a tear in the canvas or by other means. Following cold, windy weather most of the plants in the bed may be affected. The bud leaves as they develop are white, presumably because of injury to the chloroplasts; and the partially developed leaves appear constricted and white along the edges of the distal portion (Fig. 7). With warmer weather the affected plants recover quickly and grow normally except that the affected leaves do not recover completely and appear mottled, with somewhat the appearance of mild mosaic.

Blotch or Scab[1]

This disease is characterized by olive-brown blotches on the upper leaf surfaces and stems of seedlings (Fig. 8A). It has been observed in Kentucky only on light-colored seedlings starved for nitrogen. It is particularly prevalent in wet seasons on plants affected by black root-rot. Where conditions which bring about susceptibility of the plants are corrected, as by the addition of nitrate, the disease is of no consequence. Beds of plants sowed with seed treated 20 minutes in water at 52° C. were free from this spot whereas beds planted with the same

[1] Caused by the fungus, *Septomyxa affinis*.

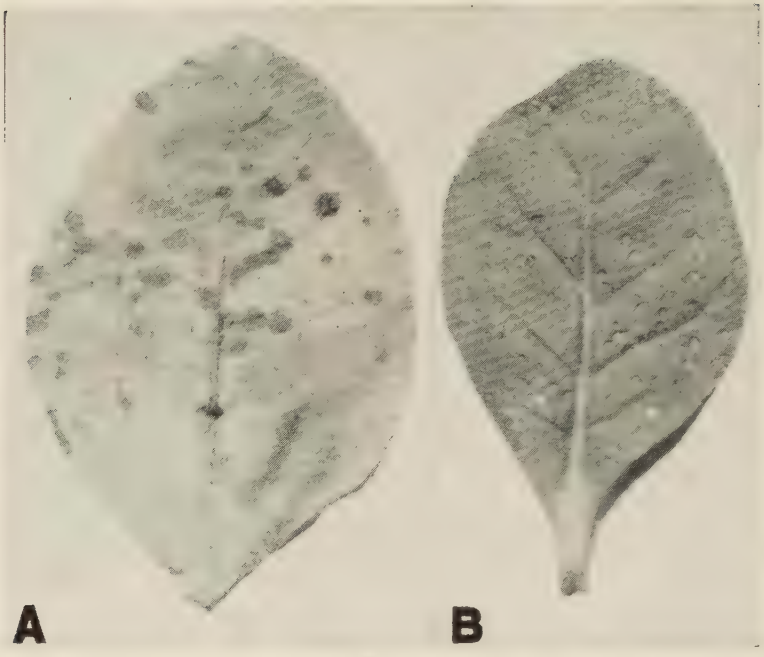

Fig. 8.— (A) Scab is common in plant beds. It occurs almost entirely on leaves which are chlorotic or yellowish. The fungus appears to be growing on the leaf surface. (B) Anthracnose on a leaf of burley.

seed untreated were affected. This suggests seed transmission of the fungus.

Anthracnose

In 1935, a leaf-spot was abundant in burley and dark tobacco in the Experiment Station beds which had been flooded several times (Fig. 8B). From these spots an anthracnose fungus (*Colletotrichum destructivum*) was isolated and found by infection studies to be capable of causing similar spots. This fungus is quite common on clovers and alfalfa in Kentucky. The flood water had swept across a pasture in which several species of legumes were growing. The disease has been seen in mild form in plant beds several times since. A similar disease caused by a fungus identical with *C. destructivum* was reported in 1941 and since, in Maryland where it caused severe injury in plant beds, and was observed in 1941 at Oxford, North Carolina, in the field on individual plants of segregating hybrids. This observation suggests that most of our tobacco varieties are highly resistant to the disease under field conditions.

ROOT DISEASES

Black Root-Rot

The black root-rot organism[1] attacks the tobacco roots either in the plant bed or the field, rotting them and eventually turning them black (Fig. 9). It may be particularly severe where tobacco is grown repeatedly in the same soil, or in plant beds where the same site is used several times without thorough sterilization. Injury in the bed may be so slight that diagnosis is difficult. In severe infestations the disease is recognized by slow growth of the plants and yellowing of leaves where there is no moisture or nutrient deficiency, and by the presence of dead, blackened roots. In the Bluegrass section, the disease used to be present in burned plant beds that were used a second time but now that resistant varieties are grown, root-rot in the plant bed is rare. It is likely to be present in plant beds in areas where the practice is to manure and use the same plant bed year after year but only when susceptible varieties are grown. Satisfactory

[1] *Thielaviopsis basicola.*

Fig. 9.— Black root-rot of burley tobacco. A healthy root of a root-rot resistant strain and the root of a susceptible variety grown in the next row. The short, stubby, black roots, with a few normal roots near the surface of the ground, are characteristic of a severe case of this disease.

plants usually are grown in these beds because steaming sterilizes the soil to a sufficient depth to permit the plants to develop. However, many of the roots penetrate the infested layer of soil and the disease may thus be carried to the field. The common practice of using a new plant-bed site each year is a means of avoiding black root-rot. Steaming permanent plant beds only enough to control weeds, has not proved effective in freeing them from black root-rot. Unless steaming is thorough it should not be relied upon to sterilize infested soil. It is particularly necessary to change the plant-bed site frequently when susceptible varieties are grown as in the dark tobacco areas of Western Kentucky. Black root-rot resistant varieties such as Ky 16 and Ky 41A have been grown satisfactorily in heavily infested plant beds so that precautions in the plant bed do not seem to be necessary if resistant varieties are used.

Black root-rot often is the cause of slow growth of tobacco in soil known to be in a high state of fertility, especially when liberal applications of manure have been made (Fig. 10). In cool wet seasons it is also found in highly fertile fields which have been in grass for many years previously. In the more acid soils of western Kentucky this organism does not become established so readily unless the land has been manured or limed and the organic matter content built up. On

Fig. 10.— Two strains of burley tobacco highly resistant to black root-rot and, in the center, a variety of burley highly susceptible to the disease. All were set at the same time, in soil infested with the black root-rot fungus.

some of these acid soils infected plants from a diseased bed make as good growth as highly resistant plants of equal size from the same bed. Where limestone is to be used on tobacco land it should be applied following tobacco and in as small a quantity as will give the desired effect in growing legumes.

All the old varieties of burley and dark tobacco and the varieties that have been developed recently directly from them have proved highly susceptible to black root-rot in infested plant beds and all of them are injured if set in infested fields.

In fields where the black root-rot fungus is known to be present and in fields that are being cropped with tobacco rather frequently a resistant variety should always be used. Experience in the cool, wet seasons of 1946 and 1947 indicates that heavy losses from black root-rot may occur in fields that have been in grass for many years previously if susceptible varieties are grown. The general use of root-rot resistant varieties therefore is desirable. In virgin soil any of the old standard varieties should prove satisfactory if plants are grown in a disease-free plant bed, and a variety is available that will produce as well as the best of the resistant varieties.

The Kentucky Agricultural Experiment Station has developed a number of varieties of burley tobacco resistant to black root-rot. Ky 16 and Ky 41A are now widely grown in Kentucky and have proved highly satisfactory. Ky 16 is proving the more valuable variety because it appears to have a somewhat wider adaptation. In some areas, however, Ky 41A appears to be more satisfactory. In cool seasons, in infested soil, the old susceptible varieties may be a complete failure while the resistant varieties produce a heavy yield under the same conditions.

The average quality of Ky 16 and Ky 41A is good, but it is not quite so high as that of the best of the old susceptible varieties grown on root-rot-free land. The chief objection to these resistant varieties has been that they have too much red leaf in the top of the plant. However, the yield is so high in the smoking grades and these grades are so satisfactory, that the returns per acre are greater than can be obtained from the best of the susceptible varieties even under conditions where root rot is not a factor. Growers who allow Ky 16 and Ky 41A to become ripe do not complain about red top leaves. In a cool wet season Ky 16 and Ky 41A may be slightly retarded in growth and time of maturity by block root-rot in fields where these varieties have been grown several years in succession.

Several new varieties such as Ky 26, Ky 56, Ky 57 and Burley

1 have been developed recently. These are more highly resistant to black root-rot than Ky 16 or Ky 41A, and some of them, as Ky 56 and Ky 57 are resistant also to mosaic. Other new varieties are highly resistant to black root-rot, mosaic, fusarium wilt, and wildfire but require more testing before they will be released. Development of root-rot resistant varieties of dark tobacco has not progressed so far as with burley, but highly resistant strains that are also resistant to mosaic are being developed.

Prevention and control: Use a variety resistant to black root-rot, if a satisfactory one can be obtained, whether the soil is infested or not, as it will reduce injury in an infested soil and prevent a clean soil from becoming infested. In the event that a resistant variety is not used the following precautions should be taken. Use a new bed site each year or steam a previously used bed at least 30 minutes, preferably 40. To prevent infestation of a field do not use plants from a diseased bed unless the field soil is very acid. If limestone has been used on the tobacco land, use a new bed each year. As manure increases injury from black root-rot, tobacco should not be grown in successive years on heavily manured land unless a resistant variety is grown. When burley tobacco is grown continuously in a field with a cover crop of vetch and small grain, the variety should always be a resistant one and preferably a highly resistant one such as Ky 57.

Brown Root-Rot

Brown root-rot is a disease of field-set plants. It may occur after such sods as bluegrass, orchard grass, or timothy, or after alfalfa, red clover, corn, and perhaps other crops. That the preceding crop itself, or its by-products, is not the direct cause of the trouble is proved by the fact that some of the best burley tobacco is grown following a virgin sod or in old bluegrass pastures that have rarely been cropped. If a heavily infested tobacco crop is followed the next season with tobacco, the second crop is not likely to have a severe attack of brown root-rot. Tobacco following weeds is usually unaffected.

Brown root-rot attacks the plants soon after they become established following transplanting. The rootlets begin to turn brown in spots and finally die, only to be replaced by new rootlets. The plants are likely to wilt in the middle of the day. Growth is slow. Finally roots are put out close to the surface of the ground and the plant commences growth (Fig. 11). This usually occurs in late July. If the soil is fertile a late but fairly satisfactory crop may result, but if the soil is infertile, the crop may be nearly a complete failure.

Brown root-rot is caused by meadow nematodes.[1] These nearly microscopic roundworms when present in a field may be found in the roots of many grasses (including bluegrass, orchard grass and timothy), in roots of most, if not all legumes, in corn, and in many weeds. The roots of ragweed appear to be almost free, while the roots of wild lettuce carry them through the winter in immense numbers. The common winter cover crops, wheat, rye, barley, and vetch, are all susceptible to the nematodes.

Roots of tobacco plants set in upturned roots of plants heavily invaded by nematodes become invaded soon after they begin to grow.

Prevention: There seems to be some difference in the relative resistance of tobacco varieties to injury by brown root-rot. Ky 33 and Canadian appear to have a moderately high degree of resistance, Ky 16 and Ky 41A seem intermediate in resistance while some other

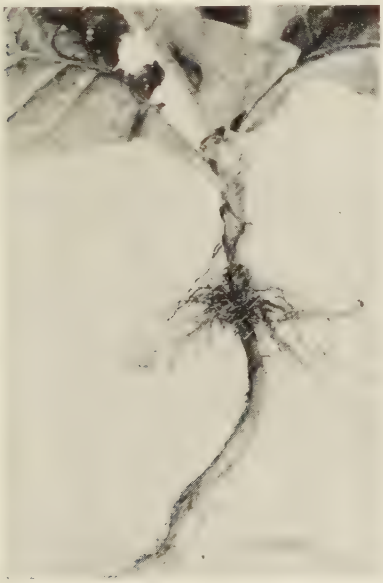

Fig. 11.— Brown root-rot of burley tobacco. Nearly the entire active root system has developed near the soil surface.

varieties are more susceptible. However, there is no proof that under Kentucky conditions any of the varieties are highly enough resistant to prevent damage. On a farm where brown root-rot has been known to occur, it is probably better to raise 2 or more tobacco crops in succession in the same field, rather than plow a new field and take a chance on the disease. In fields where tobacco is grown continuously, with a winter cover of vetch and a small grain, tobacco usually starts rapidly and shows no signs of brown root-rot.

[1] *Pratylenchus pratensis* and related species.

Root Knot

Root knot, caused by nematodes,[1] or round worms, is found occasionally in tobacco plantings in Kentucky. The tobacco roots and rootlets are enlarged at irregular intervals (Fig. 12), causing them to have a more or less beaded appearance. If the knots are broken open carefully, the small, white, spherical, female worm may be found in the knot. The disease probably occurs most commonly on tobacco growing on land previously used for a garden. Nematodes are frequently introduced into garden soil on tomato plants grown in the greenhouse or shipped from the South.

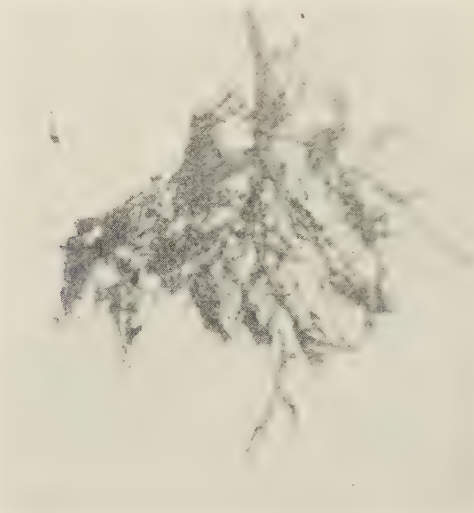

Fig. 12.— Root knot or nematode injury to tobacco roots.

Control: Root knot is not serious in Kentucky and requires no special precautionary measures except in fields where diseased plants of tobacco, tomato, or any other of a long list of susceptible plants may have been found previously. If the soil is infested it is best to sow it to bluegrass and not attempt to grow tobacco or other susceptible crops. Wheat, and some other grasses are resistant and Brabham and Iron cowpeas, as well as some other hybrids with Iron, are highly resistant to root knot. The practice of planting tomato plants brought in from the South is dangerous because root knot nematodes are likely to be introduced. Once established in a field it is almost impossible to get rid of them. Removal of the affected root systems in the fall will

[1] *Meloidogne incognita.*

greatly reduce the nematode population in the soil and injury the next year.

Pythium Soft Rot

This disease occurs soon after setting. The recently set plants wilt and, when removed from the ground, will be found to have a soft, watery rot of the buried stem. The disease is caused by a species of *Pythium*, one of the organisms responsible for damping off of seedlings of many different plants. Resetting is of little value because, when the disease first appears, there are plants in all stages of decay, some of which will not die for a week or more. It is best to disk the field and reset completely.

Club-Root

Club-root has some features in common with root-knot and could be confused with it. However, knots occur on small rootlets as well as on the larger roots in the case of root knot whereas club-root is confined largely to older roots that are very much enlarged throughout (Fig. 13). Actually the enlarged roots are made up of a succession of closely packed tumors or enlargements that are easily broken apart. The disease has been found in Campbell, Owen, Henry, Boone, Carroll, Grant, Daviess, and Fayette counties and has been found in Eastern Tennessee and in Maryland. Plants affected by club-root

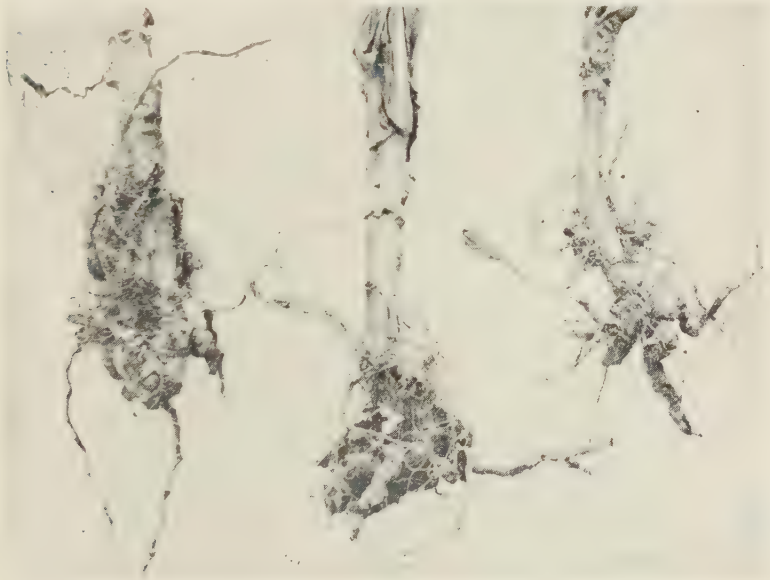

Fig. 13.— Club-root of tobacco.

usually grow slowly and rarely mature properly. In 1947 the disease appeared to have developed in definite more or less circular areas either in the center of the field or near one edge, but in 1948 there was evidence that infection had taken place in the plant bed. A portion of a field set from one bed might be entirely free from infection while the portion set from another bed might be heavily infected.

The disease is caused by a virus, very closely related to, or perhaps identical with, the wound tumor virus. The latter virus is transmitted by certain leaf hoppers so it is probable the tobacco virus is also. Tobacco following diseased tobacco is usually unaffected.

Broomrape

Broomrape is a parasitic flowering plant *(Orobanche ramosa)* that grows upon the roots of tobacco, hemp, and other plants (Fig. 14). As it is incapable of forming green coloring matter, and there-

Fig. 14.— Tobacco parasitized by a plant of broomrape *(Orobanche ramosa)*.

fore cannot elaborate its own food materials, it must take them directly from the roots of the plant upon which it lives. It produces seeds in abundance that are capable of remaining viable in the soil many years; consequently broomrape may appear in fields that have not been planted to either tobacco or hemp for a very long time. The parasitized tobacco plants take on a sickly, yellowish, starved appearance, at which time large masses of the blue-flowered broomrape can be seen around the base of the tobacco plant. It is very injurious to an occasional field of tobacco in the Bluegrass section of Kentucky.

Prevention: No way is known to prevent broomrape in fields known to be infested. Avoid planting tobacco in them. In a mild infestation it would probably be well to pull the broomrape plants from the roots of tobacco before the broomrape seeds develop. This would prevent further soil infestation, and benefit the tobacco. It has been reported from Italy that various legumes stimulate germination of broomrape seeds but broomrape does not produce seed in the legume fields. Thus it is claimed legumes following tobacco may eliminate broomrape.

Dodder

Dodder is another parasitic flowering plant that ordinarily causes

Fig. 15.— Dodder on a field plant of dark tobacco grown in a plant bed in an old lespedeza field. Dodder is a leafless plant containing very little chlorophyll or green coloring matter. The long stems are usually orange yellow.

little injury to tobacco but is a common parasite of Korean lespedeza. Where tobacco beds are located in an old lespedeza field, dodder may attack the tobacco plants in the bed and become attached to them. Then, even though most of it is pulled from the tobacco plants before setting, small bits will remain attached and be carried to the field where they will grow rapidly and practically destroy the plants (Fig. 15). It is best not to put a tobacco bed in a lespedeza field where dodder was present. If dodder appears in a tobacco bed the affected areas should be avoided when pulling plants.

LEAF DISEASES

Angular Leaf-Spot and Wildfire

Angular leaf-spot, sometimes called "rust" in the burley section, and wildfire are widespread in Kentucky and in certain years cause considerable injury to tobacco. The diseases appear in the plant bed on tender, rapidly growing plants rather suddenly during cool, rainy periods (Fig. 16). Under conditions of high humidity small water-soaked spots develop in the leaves, apparently as a result of intercellular spaces being flooded with water. If bacteria are then splashed or carried in other ways to the leaves, they readily enter through the

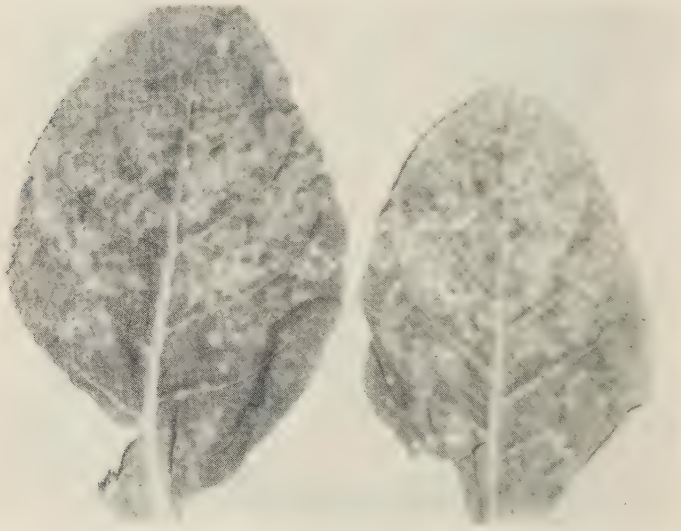

Fig. 16.— Angular leafspot on leaves of half-grown plants from a heavily infected bed. The disease at this stage is commonly called rust.

stomata into the water-soaked areas and cause infection. These spots rapidly turn brown whereupon they give the plants a scorched appearance, or in wildfire the small plants may die, partly as a result of toxin produced by the wildfire organisms.[1] Following a severe outbreak, some of the plants usually recover rapidly and as the earlier-affected leaves die, the plants may show but few signs of infection at setting time. The angular leaf-spots on older leaves have small, irregular, nearly black centers, surrounded by a narrow halo or band of yellow (Fig. 17A). With age the centers may turn nearly white. The tissues around the spot, especially on plants in the bed and on rapidly growing tobacco in the field, are often puckered and torn. The wildfire spots are usually surrounded by a broad yellow halo (Fig. 17, B). One or the other or both diseases are usually present in untreated burley plant beds where they sometimes cause considerable injury if the plants are small. Dark tobacco plants in the bed appear to be more resistant to angular leaf-spot but are very susceptible to wildfire. It is difficult to find angular leafspot on dark tobacco plants even when they are growing in the same bed with heavily infected burley plants. The diseases are carried to the field on young plants where they may spread rapidly, during rainy, windy weather (Fig. 18).

In the field angular leafspot and wildfire may develop rather suddenly on rapidly growing tobacco which previously had appeared entirely free from infection. This sometimes occurs when clean plants are set followed by several days of wet stormy weather. An outbreak, of rather general occurrence in Fayette county, appeared following a rainy period of about three days. On one of these days when the soil was wet, rain fell for about three hours. During the rain, plants about one foot tall were observed to have numerous water-soaked, translucent spots on some 6 or 7 lower leaves. The water-soaking was of the internal type as the spots were distributed evenly on the leaves on all sides of the plants and there had been no driving rain which could have forced water into the leaves. A few days later all the plants in certain areas of the field were heavily infected with leafspots, the distribution of which corresponded with that of the water-soaked spots. The bacteria that caused the spots evidently were in the soil and were splashed onto the water-soaked areas which they quickly entered.

[1] Wildfire and angular leafspot are caused by the organisms *Pseudomonas tabaci and P. angulata*, respectively. These organisms are generally put in distinct species but there is good evidence that they are variants of the same species. Wildfire cultures, after a time in storage, not infrequently produce both wildfire and angular leaf-spot, even from cultures started from a single cell. The angular leaf-spot phase at one time seemed to be more abundant in the soil than the wildfire phase but during 1950 and 1951 the reverse was true.

causing infection. Ordinarily water-soaking lasts for about 3 hours or less, but leaves have been observed to remain water-soaked overnight. The bacteria may also spread during driving rains when the leaves on one side of the plant develop heavy infection. There is, however, a

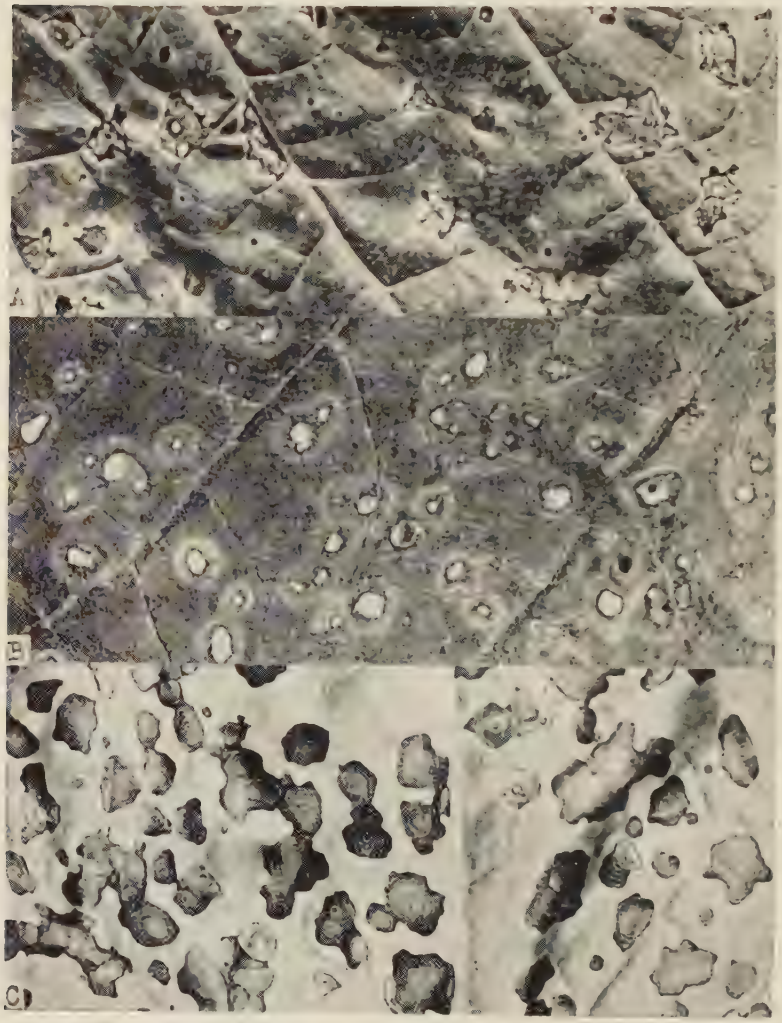

Fig. 17.— Three leafspot diseases of tobacco. Angular leafspot (A) and wildfire (B) are two bacterial diseases sometimes destructive to tobacco. Blackfire (C) on burley tobacco is probably started by the wildfire and angular-leafspot organisms on tobacco growing on land deficient in potassium.

type of spot that follows violent rain and windstorms which is the result of rain beating on leaves turned up or over by the wind. If the stomata are closed, the beating raindrops bruise the leaf tissue but if the stomata are open the water passes into the leaf and causes only a water-soaked spot which soon disappears. The bruised areas may gradually turn yellow and die, when they have much the appearance of angular leaf spot.

The bacteria that cause these leaf spots have been found to live on the roots of grasses and weeds as well as on the roots of tobacco and small grains. This explains why the bacteria may attack tobacco plants in the field that came from a clean bed, and why the diseases are found in the majority of untreated plant beds.

Prevention: If the diseases are prevented in the plant bed, there is usually little danger of their developing in the field except during protracted wet periods. Plant beds that are well ditched, so that no water will flow over them, that are prepared in the fall early enough so that the roots of plants turned under will die and decay before winter, or beds that are thoroughly steamed or methyl bromide treated in the fall should be free from leaf spots, particularly if

Fig. 18.— Wildfire on a tobacco plant nearly ready to set. Plants half grown or larger are rarely killed, but their growth may be retarded.

treated with bluestone-lime.[1] When plant beds are used each year, disked and sown to soybeans following setting, and then plowed in the fall and treated for weed control, there is no difficulty whatever with leaf spots year after year if the beds are ditched and treated with bluestone-lime. Beds plowed late in the fall or plowed in the spring and burned are likely to be contaminated with the leaf spot bacteria unless treated early and very thoroughly with bluestone-lime, as the bacteria are almost certain to be carried on the roots of plants turned under.

In the field, injury to the leaves is not so great if the plants are well nourished, particularly with potash.

Breeding for resistance: Resistance to these two diseases has been found in the wild tobacco *Nicotiana longiflora*. While this species does not cross at all readily with tobacco, a few viable seeds were obtained using the pollen of *N. longiflora* on burley tobacco. The seeds, as they germinated, were treated in a solution of the alkaloid colchicine which resulted in doubling the chromosome number in some of the hybrids with the result that they were fertile and produced viable seed. By several back crosses with burley and dark tobaccos and selection each generation for wildfire resistance, varieties have been developed that appear to be immune to wildfire and angular leaf-spot both in the plant bed and in the field.

Frogeye and Greenspot[2]

Frogeye, caused by a fungus, is common in Kentucky but is rarely the cause of serious injury to tobacco. The spots are found on the lower leaves in damp locations. They have a dead, white, parchment-

[1] Bluestone-lime or bordeaux mixture is cheap and is easily applied with a sprinkling can. It should be applied when the plants can just be seen and again 10 days later before the disease appears. Bordeaux mixture suitable for sprinkling on tobacco plant beds is prepared as follows: 50 gallons, sufficient for 66 yards of bed 9 feet wide, require 4 pounds of chemical hydrated lime (or 3½ pounds of stone lime slaked with a small quantity of water), 3 pounds of finely powdered copper sulfate (bluestone), and 50 gallons of water. Dissolve the bluestone in a bucket of water. Mix the lime into a thin paste with water in another bucket, and pour it into the water in a barrel or other container, containing about 46 gallons of water. Then, while stirring vigorously, pour in the copper sulfate solution. The bordeaux may be prepared in a wooden barrel, or 60-gallon oil barrel, and may be applied to the bed with an ordinary sprinkling can. It is best to wash out the containers before use, so that the sprinkler will not become clogged. The mixture should be stirred every time a portion is removed from the barrel.

[2] This disease is usually considered to be caused by the fungus, *Cercospora nicotianae*, but studies at this Station have demonstrated that cerosporas from several other genera of plants will also cause typical frogeye spots on tobacco and that the fungus from tobacco will cause infection of other genera. It is probable that the tobacco fungus is identical with the celery fungus and should be called *C. apii*.

Fig. 19.— Frogeye of burley tobacco. The parchment-white spots with the gray centers are typical of this disease.

like area in the center, about 3 16 of an inch in diameter. In this area is an indistinct grayish mass of spores (Fig. 19). The tissue surrounding the spot is a light orange yellow blending into the normal green of the leaf. As the yellow area sometimes becomes quite wide, the spots might be confused with wildfire. Frogeye is sometimes considered to benefit burley tobacco when it affects only the lower leaves; but some years the upper leaves are peppered with small green spots after the tobacco is cured (Fig. 20). These green spots have been proved to be caused by the frog-eye fungus which attacked the leaves a few days before cutting, though the spots are usually not evident at cutting. During curing the chlorophyll fails to break down in the infected spots. In wet seasons when infection has occurred on the upper leaves of burley tobacco and the tobacco is left in the field to become thoroughly ripe after the last suckering the lower leaves may die rapidly and large dead spots may suddenly appear on the upper leaves. Under these conditions frogeye may cause extensive loss.

Fig. 20.— Greenspot on a cured leaf of burley tobacco. This spot is caused by late infections by the frogeye fungus.

Very little is known of the life history of the organism that causes frogeye and green spot, and satisfactory methods of prevention are not known. Considering that cercosporas on other genera of plants can cause typical frogeye on tobacco it is not improbable that infection originates from wild plants. This would explain the common appearance of the disease in the field. Frogeye is a rare disease in plant beds in Kentucky.

Leaf Scald

Every year some scalding of burley tobacco leaves occurs. The scalding, usually on about two leaves of a plant, develops while the leaves are badly wilted. The parts of the wilted leaf folded together

Fig. 21.— Leaf scald of burley tobacco. (A) Two leaves badly wilted. Wilting of this kind is usually attributed to the sting of an insect. (B) A leaf such as is shown in A following recovery from wilting. Some parts of the leaf were so badly wilted that death followed. The dead areas are at first bluish green and later turn brown.

and exposed to brilliant sunlight fail to recover, turn a bluish-green and later dry and turn brown (Fig. 21 A, B). A greenish black mold develops over the surface of the dead tissue. Wilting occurs in hot weather following periods of rapid growth. It is also sometimes caused by the sting of one of the stinkbugs. If the bark is carefully peeled from the stalk of a wilted plant that has been stung, white, elongated areas of collapsed spongy tissue may be found. These are evidently the feeding areas of the stinkbug. Some burley hybrids, particularly those with the mosaic-resistant South American tobacco Ambalema, have proved to be very susceptible to scalding; others more resistant. Ky 16 appears to be almost free from the trouble.

VIRUS DISEASES[1]

Mosaic

There are many virus diseases of tobacco; the commonest and in the aggregate the most destructive is tobacco mosaic (Fig. 22). This disease is present wherever tobacco is grown. It is known to most tobacco growers, although often by some other name than mosaic. In some parts of western Kentucky it is called "walloon"; in other parts of the state, "black french," "dry-weather french," "frenching," etc. The disease is characterized by a mosaic pattern of light and dark green areas in the leaves that develop after infection occurs.

The tobacco mosaic virus appears to be quite variable. As a consequence, there are numerous field strains of the virus and symptoms of affected plants differ greatly in different fields. Certain strains cause mild mottling and no distortion of leaves while others cause prominent mottling and distortion of the new leaves. The patterns may be pure white or yellow or more commonly various shades of green. Certain strains cause burning or spotting of leaves, a condition known as *mosaic burn* (Fig. 23). Other strains never cause burn. Burn is confined largely to leaves too old to develop mottle patterns but not of full size at the time of infection. When a burning strain of mosaic is spread during topping one or two upper leaves may burn with no other symptoms of mosaic except in the suckers, which, in dark tobacco, are removed. Mosaic burn may cause extensive injury to tobacco on one farm and be entirely absent on another farm where a non-burning strain is present. Growers often confuse mosaic burn with angular leaf-spot, or wildfire in dark tobacco and some begin cutting to prevent further spread. This early cutting is not necessary.

The cause of mosaic is a virus, particles of which are too small to be seen with an ordinary compound microscope, but which are readily transferred from diseased to healthy plants by handling.

The mosaic virus has been shown to remain virulent for 52 years in cured tobacco. Hence it is practically always present in the natural-leaf chewing or smoking tobacco used by tobacco growers if this tobacco was made up in part from infected plants. As the virus is readily transferred from dried tobacco to living plants, the tobacco grower himself is nearly always the chief agent in introducing the disease into the plant bed or field. It has been clearly demonstrated that the

[1] See also club root, page 25.

hands of a man who uses natural-leaf tobacco containing the virus, either for chewing or smoking, become contaminated by handling the dried tobacco, and that he can transmit the virus readily to healthy plants while he is weeding, or pulling plants for setting. Once

Fig. 22.— A mild and a severe form of mosaic of tobacco. There are many distinct field strains of the typical tobacco mosaic. These differ in severity of symptoms produced on the plant, and in color produced in the affected leaves. Usually affected leaves are various shades of green, but some strains produce yellow blotches and others turn parts of the leaf almost white.

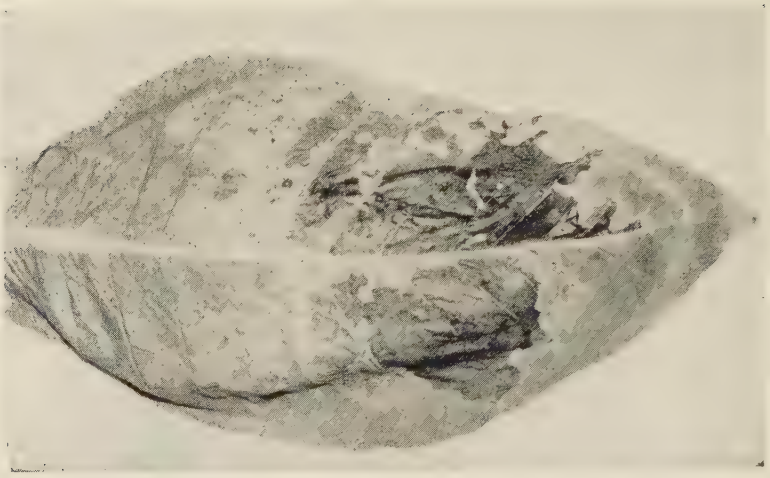

Fig. 23.— Mosaic burning often develops on one or two leaves of a plant recently infected with certain strains of tobacco mosaic. Few tobacco growers recognize this as a symptom of mosaic because at the time these symptoms appear the mosaic symptoms may not be in evidence, especially in topped tobacco.

introduced, the disease is easily spread during the operations in which the plants are handled, such as pulling, worming, topping, suckering, and cultivating. In a field where the disease was prevalent earlier, many of the suckers are likely to be diseased following cutting. The virus does not appear to be carried in tobacco seed.

Certain weeds (horsenettle and groundcherry) become infected and carry the virus from year to year. But these appear to be minor sources of the mosaic virus except in beds where there are infected weeds. While weeding the virus may be spread from these weeds to an occasional tobacco plant. If this occurs, mosaic may be abundant in the field later on. Though the problem of plant infection from weeds has not been studied, it is probably best to make it a rule never to remove any of these weeds from the bed and never to touch them while pulling plants. Infected and healthy plants may grow side by side for weeks, without the disease spreading, if the plants are not handled. During the summer the virus is spread slowly in the field from the weeds to tobacco, perhaps by insects or by tools; hence it is practically impossible to completely prevent its occurrence in fields where there are many infected weeds. Chopped tobacco stalks and other tobacco trash, carrying the mosaic virus and applied to the field at the last disking before setting may cause extensive field in-

fection. Tobacco stalks, unless they come from a field known to be free from mosaic or are put on the field during the winter and are later plowed under should not be used as a fertilizer for tobacco.

In Kentucky overwintered roots of affected tobacco plants even though dead, retain some of the virus. At the Experiment Station farm no greater difficulty has been met in preventing mosaic in plots set to tobacco each year and inoculated with the virus in the middle of the summer so that there will be a carryover in the roots, than in plots set to tobacco at less frequent intervals. The roots of tobacco readily become infected with mosaic, when inoculated, but the virus spreads very slowly from the roots to the top unless the tops are removed and sucker growth develops, whereupon the virus quickly moves into the new growth. It therefore seems safe to grow tobacco, following a heavily infected crop, without fear of infection, except in an occasional plant, if the proper precautions to prevent infection from other sources are taken.

Growers frequently express the opinion that mosaic does not injure tobacco. This is not true, except that in burley there may be no injury if infection occurs shortly before cutting. There is some evidence that the upper leaves of burley may be slightly improved in quality by late infection. Infection of all plants of either burley or dark tobacco at setting time reduces the value of the crop about 60 percent, and infection when about half grown, by about 50 percent. When plants are inoculated at topping time, dark tobacco may be injured about 25 percent. Contrary to popular belief mosaic patterns present in green tobacco are still visible in the cured leaf (Fig. 24).

Prevention: Satisfactory control of mosaic, under Kentucky conditions, appears quite simple. Exclusion from the plant bed of all tobacco trash of previous crops, such as ground tobacco stalks and trash used as fertilizer, and complete abstinence from the use of natural leaf tobacco during the weeding and setting season by those who handle the plants, usually give control. Before going to the plant bed growers should remove all tobacco from their pockets and thoroughly wash their hands with soap and water. Another simple way to prevent infection from the hands of workers is to have each of them while weeding, pulling, or setting, dip his hands in a concentrated solution of tri-sodium phosphate (T. S. P.) in water. If this is done by each worker about 4 times a day there will be little infection from this source. Tests of commercial tobacco indicate that manufactured twists and scrap are probably always free from mosaic, and

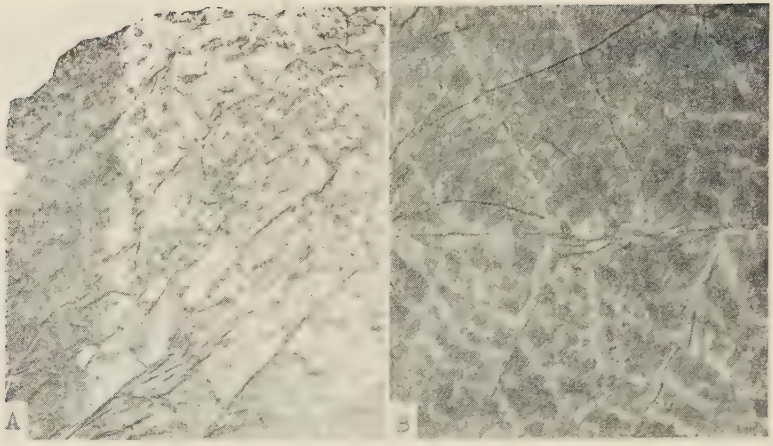

Fig. 24.— (A) Tobacco mosaic patterns in a cured leaf of dark fired tobacco. The portion with patterns was taken with transmitted light and the remainder with reflected light. (B) Portion of a cured leaf of white burley tobacco showing mosaic patterns with reflected light.

plugs rarely carry it.[1] Cigarettes and tinned tobacco, while they carry mosaic, have been proved relatively safe to use. Therefore tobacco in any of these forms may be substituted for the natural-leaf tobacco during the plant-bed season with a fair degree of safety. Horsenettles and groundcherries should not be handled while weeding or pulling plants and a bed should not be placed where infected weeds of these species are known to be present. If these weeds are found in the bed at weeding or pulling time they should not be touched. Mosaic may be introduced and spread while worming tobacco by hand. Therefore, it is preferable to control the tobacco horn-worm with one of the newer insecticides.

A much higher proportion of plants become infected with mosaic if worming is done when the plants are damp than when they are dry. It is preferable, therefore, if mosaic is present in the field, or if one uses natural-leaf tobacco for chewing and smoking while handling plants, to handle them only when dry. Mosaic may be spread from plant to plant by tools and harness while cultivating tobacco. It is therefore a good practice to go through the field about one month after setting and remove all diseased plants. Healthy plants

[1] Careful growers can provide for their own use a supply of mosiac-free chewing and smoking tobacco if, at the last suckering, they sucker and later cut for this purpose only mosaic-free plants; or they may grow a small patch of mosaic resistant tobacco from which to make chewing or smoking tobacco.

should not be handled during this operation or until the hands have been thoroughly washed. If mosaic plants are present in a field of dark tobacco at topping time they should be topped last. It is not so necessary to observe this precaution with burley tobacco especially if it is topped late. Fields of burley tobacco heavily infested with mosaic should be topped late. If topping is done with a knife and only the top of the plant is handled, there will be little spread of mosaic. If these simple precautions are taken, damage from mosaic will be negligible.

Mosaic resistant varieties.— All the commonly grown North American varieties of tobacco are highly susceptible to mosaic, but two sources of mosaic resistance have been found. One of these is a highly resistant variety of dark tobacco called Ambalema, grown in Colombia, South America. The other is *Nicotiana glutinosa*, a small, weed-like plant with small heart-shaped leaves with long petioles. Ambalema tobacco crossed with burley produces, in the first generation, hybrids susceptible to mosaic; but in the second generation mosaic-resistant burley plants can be selected. By back-crossing with burley, selecting

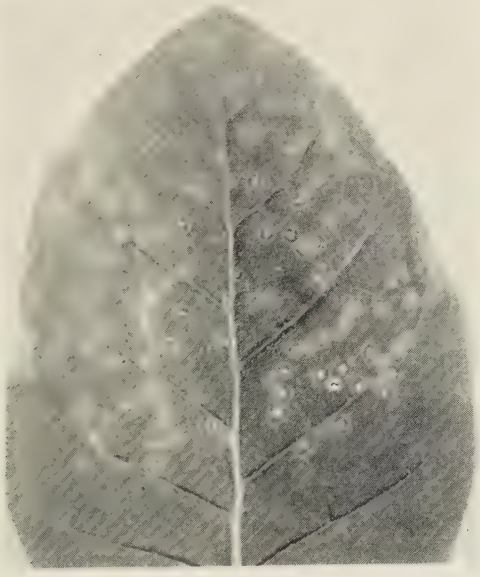

Fig. 25.— A leaf of a mosaic-resistant burley (glutinosa type resistance) showing the type of reaction produced by tobacco mosaic virus. The virus usually remains localized in the dead spots and the remainder of the plant remains healthy.

for resistance, and repeating the process several times the burley characteristics can be concentrated. Nearly all the resistant burley varieties developed in this way have had two objectionable characters. They are likely to wilt and scald on hot days, with the resulting loss of 2 to 3 leaves, and they usually have a somewhat narrow leaf with a midvein or "stem" that appears too long for the leaf, and gives it a wavy appearance. No satisfactory mosaic-resistant varieties of tobacco have been developed by crossing with Ambalema.

Nicotiana glutinosa when inoculated with tobacco mosaic responds by developing a dead spot at each point of virus entrance. The virus is then usually localized in the spots and the plant as a whole remains free from mosaic (Fig. 25). By proper breeding methods this reaction (NN) has been introduced into burley and dark varieties. Ky 56 is resistant to mosaic and highly resistant to black root-rot, much like Ky 16 in appearance but it yields slightly less than Ky 16. Ky 56 is sufficiently good for use where one has had trouble with mosaic in burley tobacco. It is being tested extensively, with apparently satisfactory results. Ky 57 is resistant to mosaic and highly resistant to black root-rot. It is used successfully by growers who have had trouble with mosaic. Several other varieties of burley highly resistant to both these diseases, and others that in addition are resistant to fusarium wilt, and wildfire have been developed but have not as yet been sufficiently tested to be recommended. As several of these latter varieties are as high yielding as Ky 16, there is no reason to believe that lower yield is associated with the mosaic-resistant NN factors. Ky 151 is a dark mosaic-resistant variety very similar to Brown Leaf. Ky 160 is a mosaic-resistant one-sucker variety. Both of these varieties are being grown extensively.

Caution: Because of the nature of resistance in the mosaic-resistant varieties the plants may die if heavily inoculated with the mosaic virus. The past few years a new disease has appeared in several areas in western Kentucky, in dark tobacco. After topping, a dark streak about an inch wide develops down one side of the stalk and eventually the whole plant dies. This seems to occur only when a grower has part of his field set to a mosaic-resistant variety and the remainder in a susceptible variety or is using a variety that is a mixture of resistant and susceptible strains. In topping, if any of the susceptible plants have mosaic, the hands of the topper become contaminated with the virus and it is spread to the resistant plants. If a mosaic-resistant dark tobacco is grown, the whole field should be set to it and not to a mixture of resistant and susceptible plants. There is less danger from

a mixture in burley as burley is now usually topped late when the plants are more resistant to this type of injury.

Use of resistant tobacco in mosaic control.— Growers who have trouble with mosaic, but do not wish to grow a resistant variety, could profitably raise a small plot of a resistant variety to provide smoking or chewing tobacco for any help who insist on using barn cured tobacco. Chewing or smoking tobacco made from a resistant variety is entirely free from the mosaic virus and can be handled without danger of infecting plants while working in the plant bed or in transplanting.

Plantago Virus

A virus frequently found in the common species of plantain *(Plantago sp.)* seems to be closely related to the tobacco mosaic virus and it may be the virus from which the numerous strains of tobacco mosaic virus were derived. In Ky 16 it causes a mottling somewhat similar to that caused by the tobacco mosaic virus, but in several other varieties of burley and dark tobacco it causes a destructive necrotic disease (Fig. 26). The plants are stunted, have dark-colored streaks on the stalks and midveins and either scattered yellow or dead spots on the leaves. Affected plants do not recover, and if infected when

Fig. 26.— Necrotic disease caused by plantain mosaic in burley tobacco. The stalk and midveins have long streaks of discolored tissue; the plant is greatly stunted and practically valueless. In other varieties of tobacco, as Ky. 16, the same virus causes a mottle disease without streaking and stunting.

young are valueless. The virus seems to be spread from plantains to tobacco when weeding or pulling plants. The disease is not common in tobacco but can cause considerable loss when numerous infected

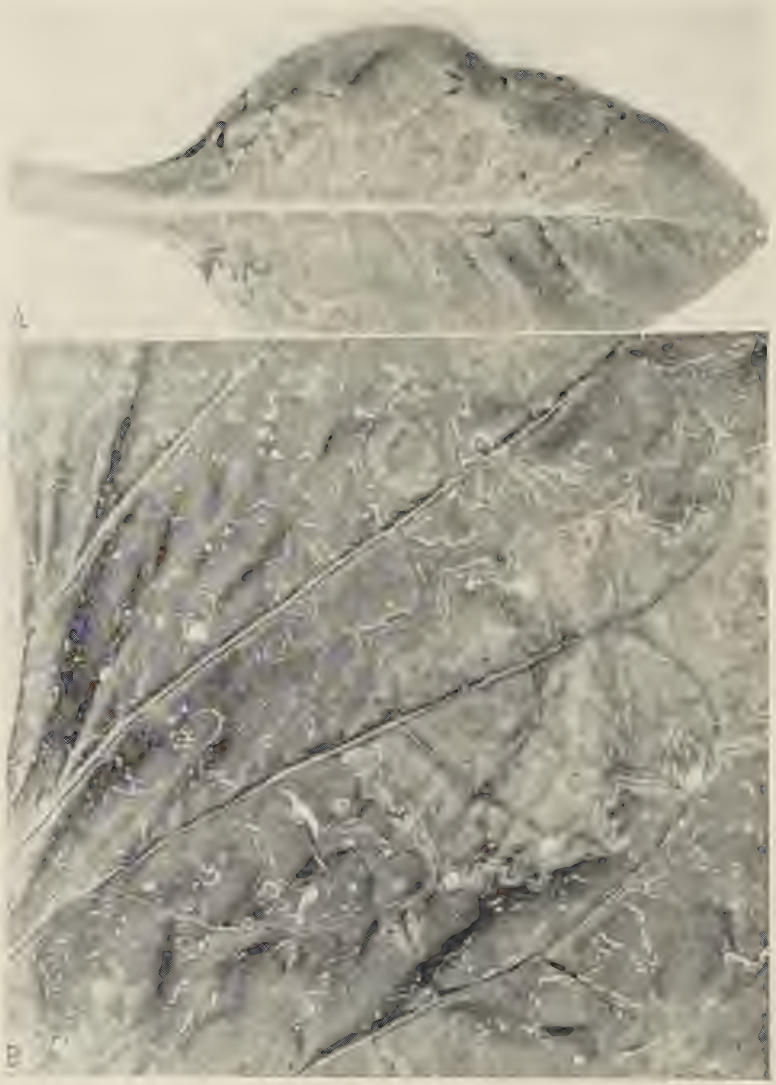

Fig. 27.—Ring-spot of tobacco. (A) A leaf from a plant in the bed. (B) A leaf from the field. The dead lines, often in the form of rings, are characteristic of the disease.

plantains are in the immediate vicinity of the bed. A plant bed should therefore not be located in an area where these weeds are abundant. The virus withstands drying just as the tobacco mosaic virus does and so it could be carried from season to season in cured tobacco.

Ring-Spot

Perhaps the most common and easily recognized of the virus diseases of tobacco, other than mosaic, is ringspot. The name describes the disease, as frequently dead rings occur, although the symptoms vary greatly (Fig. 27). Though ringspot is found in nearly every tobacco crop examined, it is usually not severe enough to require preventive measures. Sometimes it is destructive to individual plants, but rarely to many plants in a field.

The first symptoms may appear on tobacco plants in the bed (Fig. 27A) or on plants in the field almost as soon as growth begins after setting. With the exception of tobacco mosaic, it is the first virus disease to be recognizable in tobacco fields following setting. The disease is widespread in Kentucky, and appears to be a common cause of mosaic in cucumbers. It sometimes affects potatoes also.

The ringspot virus has a wide host range. It may overwinter in horsenettle, groundcherry, curled dock, and probably in several other weeds, from which it may be transmitted to tobacco probably by some insect. The virus does not remain viable in the cured leaf. It is carried in seed from affected plants and develops in an occasional seedling although the ring symptoms may not appear. It is not likely that infection through seeds is of any importance as the infected seedlings grow slowly and probably would not be set.

Streak

During the last few years this virus disease has become increasingly prevalent in burley tobacco but does not seem to be so injurious to dark tobacco. Vigorously growing plants suddenly develop a severe necrotic disease of the growing-point leaves and stalk. The stalk is marked by depressed dark areas; the midveins of the leaves have dead streaks in them, and the small veins of the leaves are darkened. The leaves curl downward (Fig. 28); the pith sometimes has large areas of dead tissue in the affected portion of the stalk. Though the affected leaves remain small and distorted, and the plant seems to be dying, growth usually is resumed and new, almost normal leaves, which sometimes show faint mottling, are produced. This change from a severe necrotic disease to almost normal growth distinguishes streak from the plantain virus disease.

Fig. 28.— Streak in burley tobacco. Young leaves are greatly stunted and distorted; veins of older leaves are discolored. The two smallest leaves on this plant are growing more normally. Affected plants appear to recover but the new growth carries the virus and is sometimes slightly mottled.

Streak is particularly prevalent near volunteer stands of second-year sweet clover. This plant along the roadside is often a menace to tobacco set close by. About the time of seed formation the insect which spreads the disease presumably must leave the clover in search of better food plants and, in the search, infects an occasional tobacco plant. A ringspot-like lesion can usually be found on a lower leaf of a streaked plant. There is sometimes a marked spread of the disease in late August and early September. In addition to the loss of leaves the disease is injurious in that plants infected when young have so much injury to the stalk that they break when speared on a stick at cutting time.

Prevention: Methods of prevention have not been worked out but the prevalence of the disease in the immediate vicinity of second-year sweet-clover plants suggests that benefits would result if second-year sweet-clover plants were chopped out in the immediate vicinity of tobacco fields *before* the tobacco is set in the field. If it is done after setting it may drive the insects to the tobacco. No benefit is to be gained by breaking out the affected tops of tobacco plants. The virus does not spread from one tobacco plant to another, and the new growth makes fairly good tobacco.

Other Virus Diseases

Several other viruses affect tobacco in the field but are usually not very injurious. Several viruses similar in nature to the cucumber mosaic virus; three virus strains, differing in degree of severity, called the etch viruses; and the vein-banding virus, commonly present in mosaic potato plants, affect tobacco. Experiments indicate that vein-banding and etch viruses may be carried from generation to generation in potatoes. While these diseases may affect a high percentage of plants in areas where potatoes are regularly grown, they do not seem to cause enough injury to be observable in the cured tobacco except in Ky 34 and Ky 35. Now that a strain of the peach aphis has become established as a pest of tobacco there is some evidence that this group of viruses may become more prevalent because they are aphis transmitted.

STALK DISEASES

Fusarium Wilt or Yellows

Wilt is a common and destructive disease in some parts of Kentucky. It is largely confined to sandy soil where it spreads rapidly and persists for years. While the fungus[1] which causes the disease appears to be widely distributed in the more fertile soils of the state, it rarely causes injury to tobacco growing in them although in the last few years it seems to be on the increase even in Central Kentucky. Attempts to infest soil on the Experiment Station farm at Lexington were not very successful. In soil that had been artificially contaminated over 15 years in succession with virulent strains of the fungus, highly susceptible burley plants were grown with only 1 or 2 percent mortality. The disease is therefore not so likely to become a factor in the better soils of the state as it is in the river and creek bottom soils.

Affected plants are usually scattered in the field, but sometimes all plants in a large area are destroyed. If present in one crop it is likely to affect a much larger number of plants in the next crop set in the same field. It is more prevalent in burley than in dark tobacco but has been seen in the latter particularly in one-sucker. The fungus enters a single root and spreads from it up the side of the plant, causing the leaves on that side to turn yellow, wilt, and die (Fig. 29). The rest of the plant may remain fairly normal although it may bend toward the diseased side. If the stalk of an affected plant is cut across, the tissue under the bark will be found to be discolored.

[1] *Fusarium oxysporum* var. *nicotianae*.

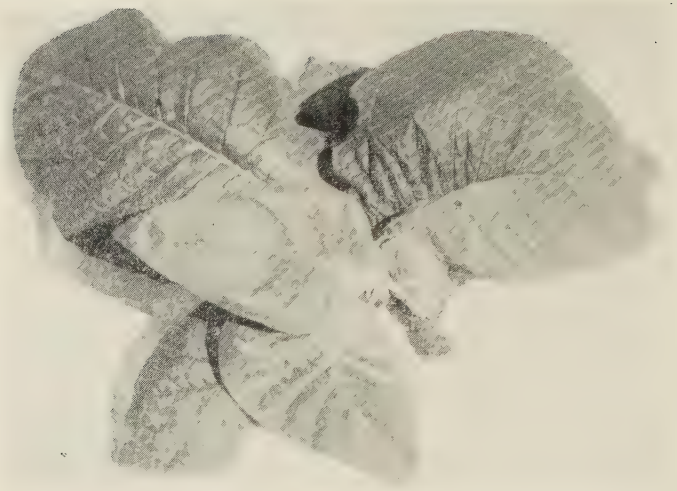

Fig. 29.— Fusarium wilt of burley tobacco caused by inoculation with a pure culture of the fungus at setting time.

There are several strains of fungus that attack tobacco. Strain 1 attacks burley tobacco and sweetpotatoes but not flue-cured tobacco or cotton; strain 2 attacks burley, flue-cured tobacco, and sweetpotatoes but not cotton; while strain 3 attacks burley tobacco and cotton but not flue-cured tobacco and sweetpotatoes. This means that tobacco, grown in fields where watermelons, tomatoes, potatoes, sweetpotatoes, cotton, or other crops have had fusarium wilt, is more likely to be diseased than that grown in fields where susceptible crops have not been grown previously.

Prevention: Fusarium wilt does not cause enough injury to most varieties of dark tobacco, except one sucker, to warrant preventive measures. The varieties of dark tobacco tested proved to be more than 50-percent resistant when inoculated at setting time, which means that in the field only an occasional plant will develop the disease. The commonly grown varieties of burley tobacco are all highly susceptible, but varieties of burley highly resistant to wilt have been developed at the Kentucky Experiment Station. Ky 33 and Ky 34 have been grown in wilt-sick soils with complete success so far as wilt is concerned, but both have a tendency to blow over in wet, windy weather; consequently they are being discarded and replaced by Ky 35. A group of new varieties resistant to wilt and highly resistant to mosaic and black root-rot are being tested for their resistance to damage by the vein-

banding virus. If a satisfactory one is developed it should replace Ky 35.

Varieties of one sucker tobacco resistant to fusarium wilt, black root-rot, and mosaic are being developed.

Sore-Shin

Tobacco plants are sometimes affected with sore-shin, a disease that causes blackening of one side or of the entire stem near the ground. It may spread up the stalk some distance. The lower leaves droop and finally the plant dies. The disease is somewhat similar in appearance to black shank. Sore-shin has not been studied extensively in Kentucky and, aside from its occasional appearance in tobacco fields, little is known about it. An outbreak was studied in Calloway county in 1934, caused by the fungus *Sclerotium bataticola*. It occurred during a damp period when the temperature for several days was about 100 F. The stalks were decayed from the ground line upward. The pith was a decayed mass in which numerous, barely visible black masses or sclerotia were imbedded. The presence of the sclerotia distinguishes the disease from black shank. It is not likely to become a serious factor in tobacco production although the fungus is common in Kentucky soil.

Another type of sore-shin is caused by the fungus *Rhizoctonia solani*. Decay starts at or near the surface of the ground and spreads upward in the pith and woody part of the stalk. The lower leaves wilt and finally the whole plant dies, but does not yellow rapidly as with black shank. Though it is similar to black shank and could easily be confused with it, the two diseases can sometimes be separated on the basis of symptoms. Rhizoctonia usually causes dead, depressed spots on the stalk above the solidly decayed portion; if the stalk is split the pith is sometimes separated into disks in the freshly decaying area but the disks are light colored rather than black as in black shank; wefts of a brownish fungus can be seen in the decayed pith; the roots are usually not decayed by rhizoctonia but are by the black-shank fungus. Though this type of sore-shin is not general, a few farmers have had considerable losses from it in dark tobacco. No control measures are known.

Black Shank

Black shank was first observed in Kentucky in 1935 near Guthrie, and about 8 miles west of Elkton. The two fields were sowed to grass and nothing further was reported from these farms. The disease also appeared in northern Tennessee the same year. It has caused con-

Fig. 30.— A root system of a tobacco plant killed by the black shank fungus. The spores of the fungus are carried over winter in all parts of the root system, the smallest bits of which are able to start the disease the next year. This illustrates why plants should be removed as soon as they show the first signs of the disease, and the soil drenched with nabam.

siderable loss in south Logan county since 1935. In 1940 it was found in several back yard plantings in Georgetown, and on one farm in Owen and another in Nicholas county. These two fields were planted to grass and no more black shank was reported from the farms or from the counties for several years. Drainage from Georgetown plantings flowed into the north branch of the Elkhorn and subsequently black shank was found down the creek, along the Kentucky river, and eventually along the Ohio river. In 1942 black shank was found in Marion county in a corner of a field where a truck had been swept

out that was used for hauling farm products from the southeastern states. Since then black shank has spread down a drainage basin from this farm and has been carried onto higher land. In 1951 tobacco on about 600 farms in the county had black shank. By 1950 black shank had been reported in 42 counties and in 1951 in over 50 and on many hundreds of farms.

The disease, when it first appears in a few plants in a low area, is usually thought to be drowning, but when it appears the following year destroying plants over a large part of the field its true nature is recognized. Some seasons there is comparatively little loss from black shank but the damage it can do is well illustrated by what happened in an 18-acre field of burley. In 1950, a very wet season, black shank appeared on a small area of overflow land and killed some plants. In 1951, 15 acres of this burley field were a total loss by August 1 and were disked, and the other 3 acres were destroyed during the next two weeks. The total loss was about $16,000. While most growers have not experienced total loss the possibility of it is ever present when tobacco is set on infested land.

Cause: Black shank is caused by a fungus[1] or mold – one that is ideally adapted to spread by water. That is the reason the disease is usually first seen in a neighborhood along a creek or in low places. The fungus is also carried in dirt clinging to shoes, machinery, animals' feet, auto and tractor tires, and such. Under very favorable conditions spores are produced on the aerial fungus which possibly are air-borne. Tobacco is probably the only crop plant in Kentucky attacked by the fungus.

Prevention: Under the conditions existing in Kentucky, where most land is unplowed, control and eradication of black shank are practical because it is possible to prevent contamination of new tobacco plots if clean tools are used. In areas where all of the land except woodland is plowed each year the chances for contamination of land that has not been in tobacco for years is great. Black shank became established in the state during the period when the practice of growing tobacco year after year on the same plot of ground was becoming accepted practice. It has spread most rapidly in areas where the farms are small and good tobacco land is limited, and where farmers trade labor and machinery from one farm to another. In areas where the farms are large and little or no labor or machinery is traded, spread has been slow.

The principles of eradication may be stated simply. Sow black-

[1] *Phytophthora parasitica* var. *nicotianae.*

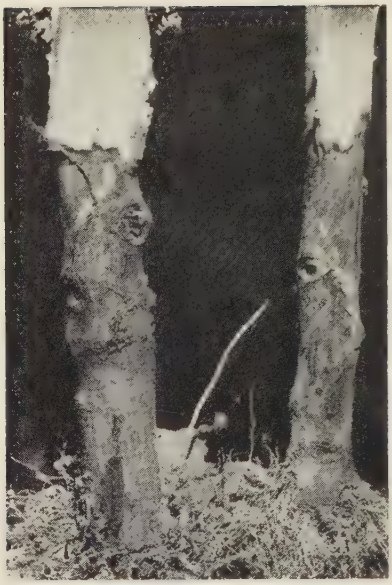

Fig. 31.— The shank of the plant is blackened from the roots upward, and the roots are decayed.

Fig. 32.— The insides of two stalks split lengthwise showing blackening and disking of the pith. The stalk on the right had evidently been infected through two leaves. There is an area of normal pith between the infected areas.

shank-infested fields to grass, preferably a grass like fescue that makes a continuous tough sod so that animals' feet will not carry dirt from the field. All tools that have been used in working the tobacco crop, hauling tobacco from the field to the barn, or in seeding the field should be thoroughly cleaned before being used to prepare a new bed or prepare a clean field for tobacco. In areas where black shank is prevalent not more than one crop of tobacco should be grown, in a 3-year rotation, until black shank is eradicated. Barn sweepings and tobacco stalks from a barn in which black shank tobacco has been housed, should be spread back on the land from which the crop came or be put on a pasture that does not drain into a creek or onto land that is to be used for tobacco. A limited amount of evidence has been gathered indicating that the black shank fungus disappears from the soil completely in 3 years and it is possible that it may disappear in a shorter period. Laboratory tests suggest that after infested soil has been thoroughly wet and dried four times, all of the heavy-walled chlamydospores have germinated and the fungus has disappeared from the soil. This could mean that one year out of tobacco may eradicate

the fungus. Much of the evidence to the effect that it persists for several years in the soil can be explained by recontamination.

A very careful worker who understands the nature of the disease may continue to grow tobacco in one field year after year, provided that at the first sign of the disease in a single plant he will carefully remove the diseased plant, put it in a bag in order not to scatter dirt, and burn it. Then he should drench the soil with a solution of some soil disinfectant such as one part nabam[1] in 400 parts of water. The appearance of a single black shank plant in a field will necessitate frequent observations to be sure that a larger area is not infested.

Breeding for Resistance: In other areas, as in Florida and North Carolina, where the disease has spread rapidly, resistant varieties have been developed that are fairly satisfactory provided they are used in a short rotation; in Florida one year between tobacco crops is sufficient. Burley varieties of a similar degree of resistance have been developed by the Virginia Experiment Station, but in heavily infested soils they have sometimes died out 100 percent. It is probable that with this degree of resistance a 2-year rotation, at least, will be necessary.

Nicotiana longiflora, the wild species that has been used as a source of wildfire resistance, is immune to black shank. An attempt is being made to transfer this immunity factor to satisfactory varieties of the various types of tobacco grown in Kentucky. If this can be done it will not be necessary to grow these varieties in a rotation in order to avoid black shank. At present (January, 1952) the immune factor has been carried through three generations of crosses with tobacco and so it is probable that it can be incorporated in the various types of tobacco.

Stalk-Rot or Hollow Stalk

In wet seasons a rot of the pith of tobacco stalks is not uncommon. Infection is reported to occur through wounds before the plant is topped or through the wound left by breaking out the top. Seed stalks sometimes become infected through wounds made when the lower branches of the inflorescense are broken off. The stalk disease spreads rapidly, and causes a soft rot of the pith and stem tissues (Fig. 33). The disease is caused by the same organism that causes black-leg of tobacco in the plant bed. No means of prevention is known and because of the rarity of the disease, it would hardly seem

[1] Nabam is sold under the trade name Dithane D14 and Parzate Liquid Fungicide. Two to 3 tablespoons of the material in a 10-quart bucket of water should be sufficient for each spot from which a plant is removed. The soil should be loosened before it is drenched.

Fig. 33.— Stalk-rot or hollow stalk produced by inoculation with bacteria from a plant affected by black-leg in the bed.

necessary to take preventive measures against its possible appearance, even if such measures were known.

Bacterial Black Stalk

The disease to which we have given this name is not a common one, but it can become quite destructive. It seems to be a disease of ripening tobacco. Specimens were received at the Kentucky Station in late August and early September, 1936, from three widely separated farms and, on August 16, 1941, the disease was found again. It has been reported several times since. Both periods were very dry although there was evidence in two of the fields of a driving storm sometime earlier, as some plants had been blown over and then bent upward. All leaves of affected plants as tall as 4 feet turn bright yellow but only the lower leaves whose midveins are decayed wilt down completely. The bark is blackened, commencing at the ground line, sometimes for 2½ feet. It is dry and smooth and has watermarks in the blackened area. Above the blackened portion the vascular tissue is discolored sometimes as much as a foot, especially the portions leading to leaf attachments. The pith is not decayed, but in the region

of the older affected area it may appear grayish and slightly wilted or may actually separate into grayish disks, just above the ground line. The roots are not affected. Affected plants may be scattered, or more than half of the plants in a large area may be affected.

When bits of discolored tissue are mounted in water, bacteria flow out of the vascular tissue. The bacteria are moderately large rods and are usually nonmotile, but bacteria from inoculated tissue sometimes show motility. In culture the colonies are nearly white, with a brownish tinge, when examined under the microscope. Too little is known about the disease to make recommendations for control. It has usually been found near a barn where animals have been kept.

LIGHTNING INJURY

Lightning frequently strikes in a tobacco patch and kills plants. A circle of plants sometimes as large as fifty feet in diameter may be struck. The plants in the center may be killed to the ground line, but the roots remain uninjured, while those on the border of the affected area may show little injury. The whole area has the appear-

Fig. 34.— Lightning injury to burley tobacco. The photograph was taken three days after the tobacco was struck.

Fig. 35.— Lightning injury to tobacco. (A) The shrunken stalk and the separation of the pith into disks give a ready means of identifying lightning injury. (B) The midveins of the bud leaves have been partly killed but in the large leaf the midvein is completely killed, giving the "gathered" effect. (C) The lower portion of the midvein has been killed. The death of the midvein does not destroy the leaf which it supplies.

ance of a spot in which a disease is spreading very rapidly from a center and for this reason often causes alarm when first discovered (Fig. 34). When lightning strikes in a patch of topped tobacco the stalk of an occasional plant may be killed and the tissues torn from between the secondary veins of the basal third of the leaves. Plants showing all degrees of injury may be irregularly scattered over the area. The injuries are quite characteristic. The large leaf veins and the stalk are most subject to injury. The affected portions of the veins turn black and shrink, giving the blade a pleated or gathered appearance (Fig. 35, B, C). The stalk may have sunken, dark-colored areas

on it or if completely killed may shrivel and become hard and leathery (Fig. 35, A). It is a peculiar fact that the stalk and midveins may be shriveled and dead and the leaves go on living normally for days, apparently because the root is unaffected and the water channels of the stalk remain open. If a stalk is split open after it has dried somewhat, the pith will be found to be separated into disks, which gives a peculiar ladder-like effect (Fig. 35, A).

HOUSEBURN

Poor curing of the tobacco crop is the cause of immense losses to tobacco growers year after year. The injury to tobacco known as houseburn is probably the greatest single factor in this loss.

Houseburn is the result of the growth of fungi and bacteria on and in the dead leaves when they become moist during periods of high humidity. It does not occur during the yellowing period except in parts of the leaf which have been killed. As organisms are not active at low temperature, houseburn does not occur in cold weather. It occurs most extensively at temperatures between 60° and 100° F and relative humidity above 85 percent which checks evaporation from green or yellow leaves and causes dead, brown leaves to take up moisture. Suckers left on the plant tend to induce houseburn in the leaves in contact with them.

To prevent houseburn several essential points in curing tobacco should be understood. These are as follows:

1. Tobacco should be cut when it is properly ripened; that is when there is an accumulation of food material in the leaves principally in the form of starch. The leaf is then a lighter green, and has a flecked appearance. Ripe tobacco leaves are brittle and snap when folded between the fingers.

2. Curing is a life process during which the green coloring matter breaks down and the leaf becomes lemon yellow. The starch is used in the process and other contents of the leaf are changed. Curing and yellowing are hastened by rather rapid wilting and retarded when the leaf is full of water. Besides the loss of water in drying, the leaf loses about 30 percent of its weight during the curing process. The presence of suckers on the stalk during curing increases the loss of leaf weight in the attempt of the plant to keep the suckers alive. Drying and death of the plant are accelerated by splitting the stalk. It is therefore likely that splitting the stalk in harvesting tends to increase the weight of the leaf, as compared with spearing. The death of portions of the leaf from bruising, frost, too rapid drying, or other

cause prevents the leaf from curing, and produces green patches in the cured leaf.

3. Following yellowing the leaf quickly dies, although the stalk remains alive for a longer time. Death of the lower leaves naturally occurs first and death of the edges of the leaves precedes that of the remainder. When yellowing is completed and the tissues are dying, the remainder of the curing process is primarily the slow drying of the leaf.

4. Browning or reddening that accompanies the death of the leaf is caused by oxidation of substances in the leaf. It proceeds more completely at higher relative humidity and more rapidly at higher temperature. Each time the tobacco becomes damp or "comes in case," the depth of color increases. As a premium is paid for light-colored burley tobacco, the cured leaf should be kept dry, except possibly tobacco originally cured green or piebald.

5. Leaf activity nearly ceases at 40° F, but becomes more active as the temperature is raised. At 125° F the cells of the leaf are rapidly killed, while at 115° F longer exposures kill the leaf. The best temperatures for the first stage of curing or the yellowing process are between 60° and 90° F. A barn to which artificial heat is not applied rarely becomes too hot but it may readily become too cold for proper curing.

6. Relative humidity or the percentage of saturation of the air at a given temperature is one of the most important factors in curing. Micoorganisms begin to develop on the leaf at a relative humidity of 80 to 85 percent but sufficient darkening of the leaf to result in lowered value can occur in some seasons at relative humidity as low as 75 percent. If the relative humidity goes much lower than 65 percent, the tobacco may dry too rapidly, resulting in mottled or green color. Thus the best relative humidity is 65 to 70 percent. This need not be maintained constantly, but each day's curing conditions should average near this value. At ordinary temperatures, a rise of 20° F changes the relative humidity of a saturated atmosphere to about 50 percent. In other words, the water-holding capacity of the air is doubled by a rise of 20° F. This explains why use of heat in a barn prevents too high relative humidity.

With these facts in mind the principles involved in preventing houseburn and too dark a color in the cured leaf are more readily understood. The tobacco should be wilted as much as is practicable before being put into the barn. It should then be kept at a temperature between 60° and 90° F, and at a relative humidity averaging about 65 to 70 percent. The relative humidity may be determined

by the feel of the tobacco. At a relative humidity of 55 to 60 percent at normal temperature, tobacco is dry to brittle, at 65 to 70 it is dry to low case, at 75 to 80 percent it is low to medium case, and at 85 to 90 percent it is medium to high case. The conditions in various parts of the barn can quickly be determined if the barn is equipped with a series of ropes hung from screw-eyes or pulleys from the top of the barn and extending to the floor. A series of 3 or 5 across the barn may be sufficient. A few cured flyings are wrapped in a piece of tobacco cotton 12 inches long by 6 inches wide. Several samples are tied to each rope so that one comes at each tier level. A knot in the rope at the floor indicates that the samples are in proper position. The barn can be quickly surveyed by pulling each sample down and feeling it.[1]

After the tobacco is cured, it should be bulked down, as soon as it can be brought sufficiently into case for handling, and stripped, graded, and again bulked as soon as possible. It should be remembered that each time tobacco becomes damp, either during or after curing, the color is darkened and there is danger of houseburn.

In curing fire-cured tobacco the same principles apply, but the premium price is obtained for darker color, and the activity of the microbes is reduced by the wood smoke deposit on the leaves; consequently a higher relative humidity, probably about 80 to 85 percent should be used. The tobacco should hang in the barn for 3 or 4 days to bring about yellowing. This may be hastened about the fourth day by slow fires which raise the temperature to about 85° to 90° F, if the proper humidity can be maintained.

Slow, very smoky fires impart the desired smoky aroma to the tobacco. When the cure is completed, slow fires should be built during periods of high humidity.

RECOMMENDATIONS FOR CONTROL OF TOBACCO DISEASES IN KENTUCKY

Every tobacco grower should try to reduce the chances of crop failure as much as possible. There are numerous diseases of tobacco, some of which can be prevented completely by the right management of the crop. It is not always easy, of course, for a grower to become familiar with the details of each of the many diseases that attack tobacco and with the methods of prevention recommended for each. By closely following the summary of recommendations given here for control of tobacco diseases, however, a grower should be able to

[1] For a more complete discussion of the principles of burley tobacco barn operation, see Ky. Agr. Expt. Sta. Bul. 501.

protect his crop against all diseases for which control methods are known, without requiring a detailed knowledge of any one of them.

Seed

Plant seed of a satisfactory variety resistant to black root-rot, if possible, and plant no other kind until a better variety has been found and has definitely proved itself to be better. If mosaic has caused losses, there are satisfactory varieties available that are resistant to it. In fields where fusarium wilt has caused losses to burley tobacco in the past a fusarium wilt-resistant variety should be used. Varieties combining resistance to black root-rot, mosaic, and fusarium wilt are now available.

Plant Beds

In former editions of this bulletin it was recommended that a new plant bed site be used each year. However, growers who are equipped to steam or gas treat beds in the fall have had success with control of the common bed diseases if the beds are steamed or gassed thoroughly. The blue mold fungus is carried from one year to another in burned beds but it is not proving to be a serious disease except once in about six or eight years. Beds plowed early in the fall are less likely to have wildfire than late fall plowed or spring plowed beds. A bed should not be located where there are many plantains or rib grass, ground cherries, or horse nettle because of the danger of mosaic. Beds should be so located that it is not necessary to go through the barn lot or across a field that previously had black shank in order to reach it. Never use ground tobacco stalks or other tobacco material, unless sterilized, on the bed as a fertilizer, because it is nearly certain to introduce mosaic. Commercial fertilizers are safe and are as effective as tobacco materials.

Serious injury occurs in dry periods from the use of too much fertilizer on the bed. Consequently, about 30 pounds of 6-8-6 or comparable fertilizer should be used on a steamed bed 12 feet wide by 100 feet long, or about the same amount of 6-8-0 or comparable fertilizer on a burned bed, because the wood ashes furnish enough and sometimes too much potash. If small plants turn yellow during a dry period the bed should be heavily watered to carry the fertilizer salts, that have accumulated on the surface, down into the soil. In watering beds use water that is free from all possibility of contamination by the black shank fungus.

To produce stalky plants sow a level teaspoon of seed on 35 to 45 feet of bed 12 feet wide. Sufficient bed space should be provided so

that beds need not be pulled over more than twice. Repeated pulling spreads mosaic. When the plants are established in the bed; and again 10 days later sprinkle the bed with 3-4-50 bordeaux mixture (bluestone-lime) at the rate of 1 quart per square yard or 50 gallons to a bed 12 feet wide by 150 feet long or 9 feet wide by 200 feet long. Heavier applications are not injurious. The two applications should be completed before the plants are the size of a dime. Another application should be made immediately following weeding if this is done after the second application. This prevents the bacterial diseases, angular leaf-spot and wildfire from developing in the bed. As a further precaution, ditch around the bed to keep surface water from flowing over it. The grower should have a good sprayer or duster on hand in case blue mold develops in the neighborhood. Application of ferbam or zineb should be made twice a week and after every rain, beginning as soon as the disease is reported in the neighborhood.

Chewing and Smoking While Handling Plants

It has been clearly demonstrated in Kentucky that cured tobacco is the source of most of the mosaic infection of tobacco plants before and during transplanting. Therefore do not use natural leaf tobacco for either chewing or smoking and do not carry it or otherwise handle it while working around the plant bed. If natural leaf tobacco has been handled recently, scrub the hands thoroughly with soap and water before handling plants in the bed. If natural leaf tobacco has been carried in the pockets, brush them out, after which plug or twist tobacco may be substituted. Commercial plug, twist, and scrap chewing tobacco usually are free from mosaic and are much safer to use while working with plants than natural leaf tobacco. Pipe smokers who work with tobacco plants should use a brand of canned smoking tobacco rather than the natural leaf. Manufactured cigarettes probably are safe to use while working with the plants. It is preferable, however, to use no tobacco whatever when working in the plant bed. Growers who wish to chew or smoke natural leaf tobacco during the plant-bed and setting seasons should raise a mosaic resistant variety of tobacco for the whole crop or at least enough to make up a supply of mosaic-free chewing tobacco. A concentrated solution of trisodium phosphate destroys mosaic on the hands immediately. If a bucket of solution is kept at the bed during weeding and pulling and the hands dipped in it occasionally and setters do the same, mosaic can be largely prevented even when help is used who chew natural leaf tobacco.

Field Practices

Do not set plants from a bed known to be affected with black root-rot unless the field soil is known to be distinctly acid. Do not set plants from a neighbor's bed unless it is known positively that no barn-cured tobacco has been used by workmen while weeding or pulling plants and that there is no black shank on the farm. Soil high in organic matter, liberal applications of high-grade fertilizer, and liberal applications of manure all tend to reduce the injury from the bacterial leaf spot diseases. They also reduce firing and increase yield and quality, especially in dry seasons.

The few mosaic plants found at first cultivation or at any time when the plants are small should be removed from the field, preferably ahead of cultivation. If this is done by hand, healthy plants should not be touched until the hands have been washed with soap and water. If mosaic plants are found in burley fields at topping time, they may be left untouched until cutting time, or topping may be delayed until most of the plants are in bloom, when all may be topped together without injury to the crop. Mosaic causes more injury to dark tobacco when spread at topping time than to burley because dark tobacco is topped earlier than burley. Consequently efforts should be made to have the field free from mosaic at topping time. If mosaic plants are found they should be passed without touching and topped last. If black shank appears in a field the field should preferably be put in grass and all tools cleaned thoroughly before they are used to work in the new field.

Horn-worms should be controlled by dusting rather than by hand worming. Handling the plants may spread mosaic, especially when the plants are wet.

Curing

To produce well-cured leaf and to prevent houseburn in burley tobacco keep the relative humidity between 65 and 70 percent. Relative humidity above 85 percent is almost sure to darken tobacco and reduce its value, while long exposure to such high humidity may cause houseburn. Every barn should be equipped with ropes, hung from the rafters, on which cured samples of tobacco wrapped in tobacco cotton are tied. By pulling these down and feeling them the condition of the tobacco in any part of the barn can quickly be determined.

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